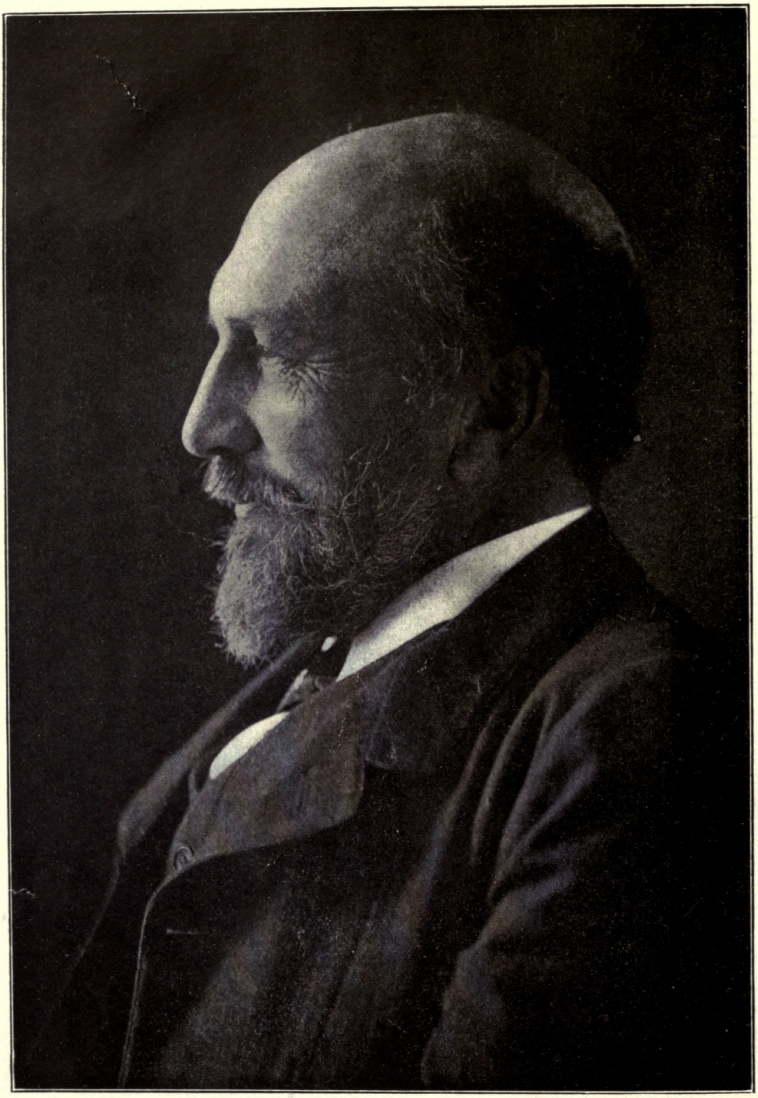
VOLCANIC STUDIES



TEMPEST ANDERSON.

VOLCANIC STUDIES

IN MANY LANDS

BEING REPRODUCTIONS OF PHOTOGRAPHS TAKEN BY THE AUTHOR

By TEMPEST ANDERSON

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PREFACE

DR. TEMPEST ANDERSON and I became friends when brought together by official duties in 1881 at the meeting of the British Association in York. A common interest in the Alps and in volcanoes increased the intimacy; and when we both acquired more command of our time, he by gradually retiring from medical practice and I by my return to Cambridge in 1905, we often met and discussed our favourite subjects. I knew that he intended to bring out a second volume of *Volcanic Studies*, which was to contain examples of the districts which he had visited since the former one was published (1903). We discussed the project shortly before he started on his fatal journey to the East Indies, and I had written to him about it only two or three weeks before receiving the news of his death on August 26th, 1913.

Some time afterwards I entered into communication with the Yorkshire Philosophical Society, to which he had been a most liberal benefactor, urging its representatives to undertake the publication of that supplementary volume, as a memorial to one who had been an honour to the Society and to the city of York. At the same time I offered to do everything in my power to aid in the publication by writing a text to accompany the selected plates and acting as Editor of the volume. Through the good offices of

Mr. George Yeld, a yet closer friend and frequent companion in travel of Dr. Anderson, the matter was ultimately arranged, and the result is now in the readers' hands. The appearance has been retarded by more than one obstacle. It was some time before the Society was in a position, as inheritors of Dr. Anderson's collection of photographs and of a handsome legacy, to move in the matter, and delays arose from other causes, for which I am not responsible—one or two of them indirectly connected with the war.

With one exception this volume includes work done since 1902. The former volume, published at the end of that year, was in the press when Dr. Anderson, together with Dr. J. S. Flett, a distinguished member of our Geological Survey, were commissioned by the Royal Society, in the early summer, to investigate the recent disastrous eruptions of the Soufrière in St. Vincent and Mont Pelée in Martinique. So striking were the effects of these that he kept the book back in order to include three illustrations of the former and one of the latter. The full account of the expedition was, however, published as a Joint Report to the Royal Society, in the *Philosophical Transactions*, and was illustrated by many reproduced photographs. In the later months of 1906 Dr. Anderson visited in succession the volcanic districts of Mexico and Guatemala, and in the earlier part of 1907 returned to St. Vincent and Martinique in order to study the effects of denudation and the new growth of vegetation during the interval, almost five years, since his former visit.

In the spring of 1908 Mr. G. Yeld and I were, by invitation, Dr. Anderson's companions on a journey to Sicily, which was to be devoted more especially to a close study of the Val del Bove on Etna and to introducing me to the Lipari Islands. These plans, however, were unfortunately frustrated, almost at the outset, by an accident to Dr. Anderson, which seemed nearly inexplicable, for he ruptured an important muscle above the right knee in stepping down, for less than half a yard, from a bank on to a path. But I had thought before it happened that he seemed "out of condition." I suspect that his general health had suffered more than he supposed from an attack of ptomaine poisoning in Mexico, and he had given himself less opportunity of regaining full vigour by his good nature in constantly undertaking journeys to lecture on the interesting districts which he had more recently visited. His recovery from this accident was slow, and after his return to England an operation was necessary in order to avert permanent lameness. The effects indeed had not wholly disappeared when he left England to spend the later part of 1909 and the earlier of the following year in visiting New Zealand, Samoa, and Hawaii. I was again his guest on the Yorkshire moors in the summer of 1912, when I was so impressed by signs of diminished physical vigour and of mental fatigue as to tell Mr. Yeld that, unless his health distinctly improved, his friends in York should try to dissuade him from undertaking the contemplated journey to the East Indies. But late in that year, when he came for a parting visit to my house in Cambridge, he seemed so much better that

I bade him farewell in good hopes of welcoming him back and once more discussing the present book.

It was not so decreed. The news of his death reached me in September 1913, when I was expecting shortly to hear of his arrival in England, and I have done my best to accomplish his wish. As Virgil wrote, *His saltem accumulem donis*. I can endorse every word Mr. Yeld has said in the short memoir included in this book, a reprint, with a few additions, of one which he contributed to the *Alpine Journal* (vol. xxvii. p. 417). Anderson was one of the most kind-hearted, generous, and lovable of men —one who never forgot anything that would give pleasure to a guest, who had, as it has been well said, a genius for friendship. His notebooks are full of memoranda to do some little kindness for this person, to send certain photographs to another, and the like, and his promises were always kept. Wherever he went he was quickly at home with those whom he met, and his close observation, his wide experience, and his marked intellectual power made him always a welcome guest. We who have lost him will not see his like again.

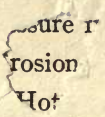
I had expected to find in Anderson's diaries ample materials for a text to accompany the photographs which have been selected for this volume, because I had observed that, when at work with his camera, he always made careful memoranda in a little notebook. But to my surprise I found, on going through those which were among his papers, that the entries were very brief. The photographs themselves, aided by his retentive memory,

sufficed for his lectures and scientific papers. To the latter I have referred whenever possible, making use also of the authorities named in the several articles. In writing these I am indebted to Dr. F. H. H. Guillemard for much kind information about the East Indies; to Mr. Leslie F. Taylor, who accompanied Dr. Anderson to Java and Luzon, for identifying the photographs taken on that last journey, and for brief but most useful notes on them; and to Mr. G. Yeld, Vice-President of the Yorkshire Philosophical Society, for searching out and forwarding to me the necessary materials.

CONTENTS

LIST OF PLATES

Several of the photographs in this volume have been already used by Dr. Anderson to illustrate his communications to the *Philosophical Transactions of the Royal Society*, to the *Quarterly Journal of the Geological Society*, and to the *Journal of the Royal Geographical Society*, but in all cases the plates have been made (by Mr. Cameron-Swan) from the original negatives, which, with the whole of his collection, are now in the possession of the Yorkshire Philosophical Society.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VOLCANIC STUDIES

I

IN MEMORIAM: TEMPEST ANDERSON, M.D., D.Sc.[1]

By G. Yeld

By the death of Dr. Tempest Anderson on August 26th last, the Royal Geographical Society, the Yorkshire Philosophical Society, and the Alpine Club lost a distinguished member. Tempest Anderson had for many years devoted much time and attention to geological pursuits, especially to the study of volcanoes and seismic phenomena. His practical knowledge of this department of science was probably unsurpassed. At the time of his death he was on his way home after paying a long-purposed visit to the volcanoes of Java and the Luzon. An attack of enteric fever seized him while on the Red Sea and quickly proved fatal. He was buried at Suez.

He had on various occasions previously had narrow escapes of losing his life when engaged in scientific travel. During a visit to Mexico for the Geological Congress in 1906, ptomaine

[1] Reprinted, with additions, from the *Alpine Journal*, November 1913.

poisoning caused him a severe illness; and when, in company with Dr. Flett, on a mission from the Royal Society to Mont Pelée and the Soufrière, he only just escaped destruction from a sudden eruption of the former mountain. It is a pathetic ending to his busy life that, when at last time and opportunity were granted him to visit Java and the Philippines, and after he had secured a large number of those artistic and instructive photographs which have made his name so well known to all who are interested in geography and geology, he should have been carried off by death when more than half-way on his voyage home.

Tempest Anderson, the son of a well-known York doctor, William C. Anderson, who belonged to an old Yorkshire family, was born at Stonegate, York, in 1846. He was educated at the ancient school of St. Peter's, York, in which he ever took a kindly interest, and where he was always enthusiastically received by the boys, and at the University of London. He was a student at University College, where he greatly distinguished himself, and of which he was elected a Fellow. He took the London M.D. degree in 1873, and in 1904 the University of Leeds conferred upon him the honorary degree of Doctor of Science. Dr. Anderson took a special interest in all that concerned the eye, and soon acquired in the North of England a great reputation as an oculist. He published various articles on this branch of surgery in the medical periodicals.

He was elected to the Alpine Club in 1893. He paid many visits to the mountains and knew the Western Alps thoroughly.

He was well known at the frequented alpine centres from the Eggishorn to the Montanvert, and from the Gemmi to the Vittorio Emmanuele Refuge on the Grand Paradis. In these districts he took many beautiful photographs. His photograph of "The Ridge of the Petit Flambeau," near the Col du Géant, was chosen as one of the best examples of mountain photographic art at the Alpine Club Photographic Exhibition in December 1912, and was reproduced in the *Alpine Journal* of February 1913. The photograph of La Vierge was little inferior in finish and effect.

But it was as an explorer and photographer of volcanoes that he gained a reputation which may, without exaggeration, be described as international. In the preface to his *Volcanic Studies*[1] he says:

"For the last eighteen years I have spent the greater part of my holidays in exploring volcanic regions, including Vesuvius (twice), Etna, the Lipari Islands, Auvergne (several times), the Eifel (repeatedly), the Canary Islands, Iceland (two long visits), and various British extinct volcanoes now and again; in 1900, the district of the Grand Cañon of the Colorado in the Arizona Desert, which contains many extinct volcanoes; the Snake River and Columbia Basalts; the Crater Lake in the Cascade Mountains in Oregon, and the Yellowstone Park."

He visited the Soufrière and Mont Pelée as the accredited representative of the Royal Society in conjunction with Dr. Flett

[1] London: John Murray, 1903, page x.

in 1902, returning to them in 1907 and examining, during the same journey, the volcanoes of Mexico and Guatemala, and in 1909 those of Matavanu in Savaii, Hawaii, and New Zealand; and in the one from which, alas, he never returned home, the volcanoes of Java, Krakatau, and the Philippines. He had also visited South Africa with the British Association, when he took, amongst other pictures, some fine photographs of the Zambesi Falls.

In addition to communicating to the *Alpine Journal* articles on such subjects as Vesuvius, Stromboli, Jaujac (in Auvergne), and the Skaptá Jokull, he read before the Alpine Club papers on the Arizona Desert, two ascents of the Soufrière, and an ascent of Matavanu.[1] Had he returned to us from his recent journey he would have been able to bring before our eyes, with his more than eloquent photographs, the features and formation of the terrible Krakatau.

It was the present writer's good fortune to accompany him on many occasions, not only in the Alps, but also in the still primitive parts of Auvergne and the Lipari Islands. No one could possibly be a more genial companion. Whether it was a breakfast at which the fowls of the establishment endeavoured as of right to share the food with us, or an entomological night in a ramshackle chamber with walls adorned in the style of the apothecary's shop in *Romeo and Juliet*, or a long tramp (Anderson

[1] He also read, as will be seen by the references in the following pages, papers on some of the districts mentioned in this volume, to the Royal, the Geological, and the Royal Geographical Societies.

was a very good walker) with two mules laden with baggage, and hampered with two unsatisfactory muleteers, he was always prepared to make the best of things, with a humorous resignation which reconciled one to every inconvenience. He had a large fund of anecdote, and could quote from it aptly and effectively.

I soon learnt to share his interest in volcanoes, and we had many adventures together on Vesuvius and Somma; we watched at close quarters for many hours Stromboli erupt at intervals of twenty minutes; we explored Jaujac's basalt columns (a view of which will be found opposite page 74 in the first series of *Volcanic Studies*) and the dykes of the wonderful Coolins in Skye.

He was for many years the moving spirit in the Yorkshire Philosophical Society, and both as Secretary and President laboured hard for its success. He gave to it a very fine Lecture Theatre, now known as the Tempest Anderson Hall, which was opened by Dr. T. G. Bonney in June 1912, on which occasion Dr. Anderson was presented with his portrait, painted by Mr. William Orpen, A.R.A., as a mark of the Society's grateful appreciation of the invaluable work which he had done for it.

To those who lectured before the Yorkshire Philosophical Society he extended a gracious hospitality in the wonderful old house in which he lived in Stonegate, one of the most famous of York's historic streets of timbered architecture and narrow roadway. Here, under the shadow of the Minster, his family had resided for very many years. The garden was a revelation

to his guests, for the lawn reminded one of the turf in an old college quadrangle, and a fig tree flourished under his study window. Lord Plunket, Sir Alfred Pease, Sir Everard im Thurm, Colonel Hellard, the late Sir William White, the late C. E. Mathews, Prof. T. G. Bonney, the former Bishop of Bristol (Dr. G. F. Browne), Dr. D. W. Freshfield, and Dr. T. G. Longstaff had been his guests on these occasions, some of them more than once. He was a perfect host.

He had served on the Councils of the Royal Geographical, the Geological, and Linnean Societies, had been Tyndall Lecturer on volcanoes at the Royal Institution, and a Vice-President of the British Association, at whose meetings he was a regular attendant, often describing and illustrating the results of his visits to volcanic regions.

Tempest Anderson was, with reason, very popular in his native city of York, where he did much excellent work both professionally at the York Hospital (where, as mentioned before, he had a very wide reputation as an oculist) and informally in many ways. He was a magistrate and filled the office of Sheriff in 1894. Scientific and Archæological Societies of all sorts found in him a hearty supporter. Town-planning was one of his many interests. The experience acquired during his travels (he was a very observant man) bore fruit in all sorts of ways. For instance, the York Waterworks, of which he was a Director, benefited largely by his visits to American water undertakings, and have become famous for their up-to-date arrangements.

Tempest Anderson had a singularly lovable nature. He had a gift for forming and retaining friendships. Honest as the day himself, he accepted the good faith of those who differed from him, and never used hard words of them. Never extravagant in his expenditure on himself, he gave a liberal support to a large number of societies and institutions, whilst in private his charities were generous and manifold and only very partially known even to his intimate friends.

He will be deeply regretted by a large circle of friends in the city of York, in the Alpine Club, and in the scientific world.

A tablet to Tempest Anderson's memory has been placed in York Minster by members of the Yorkshire Philosophical Society, and other of his many friends. The inscription upon it is appended:

To the memory of Tempest Anderson, M.D., D.Sc., distinguished alike as Surgeon, Traveller, Man of Science, and faithful citizen of this ancient City of York, his many friends dedicate this tablet.

Born in York 1846, *died at sea* 1913, *and was buried at Suez.*

II

AN ERUPTION OF VESUVIUS IN 1906

In the former volume Dr. Anderson has given the results of his visits to Vesuvius, the chief and last of which was in September 1898, when the principal cone and a parasitic one, which had been formed near its base, were explosively venting steam and ash, while streams of lava were flowing from fissures in the former, one of which was descending towards the Observatory. During the following years it became evident that the pressure within the volcano was again on the increase, and on the morning of April 4th the south-south-eastern flank of the great cone was cleft by long fissures, and from the base of one of these, near the Casa Fiorenza, at a height of some 2,460 feet above sea-level, a small flow of lava issued, while a great jet of steam, laden with dust and scoria, shot up into the air.[1] Then came a slight pause, but between the 6th and 7th of that month, "while the great threatening pillar of black and brown lapilli was looming ever more colossal

[1] Several accounts of the eruption were published at the time and afterwards. That given above is mainly a summary of one communicated by Professor Giuseppe de Lorenzo to the Geological Society of London on May 9th, 1906, and printed in the Quarterly Journal of that Society, vol. lxii. p. 476. Some brief notes by Dr. Anderson, written in a small pocket-book, have also been used.

towards the heavens, . . . deeper and longer fissures than before yawned in the south-eastern wall of the cone." From three of these volumes of steam laden with scoria and a mass of fluid lava poured down the slopes towards Boscotrecase, laying waste on its route farmhouses and vineyards.

Again there was a short pause, as if to prepare for the maximum outburst, in the course of the night of the 7th to the 8th of April. During the evening of the former day explosions from the principal crater shot up fragments of incandescent material to a height of 3,000 feet above its rim, and they became most violent between midnight and dawn on the 8th. They shook the earth as far as Naples; they threw out enormous quantities of scoria and dust. A strong south-west wind showered these down on the villages of Ottajano and San Giuseppe, burying them beneath a layer of lapilli more than two feet thick, crushing in roofs and killing about 200 of the inhabitants, most of whom perished in the church of the latter place. The cloud of finer dust crossed the Apennines and swept over the Adriatic to Montenegro. Simultaneously with these explosions, the cone was cleft more deeply than before, and a fresh stream of lava poured forth, overflowing the older one, and cutting off the village of Boscotrecase in two places. (Plate V shows the lava stream where it had passed beneath a railway bridge, between that village and Bosco Reale) and reaching, in the course of a few hours, the cemetery of Torre Annunziata, against the walls of which it stopped.

This ejection produced a partial relief, but though the phase

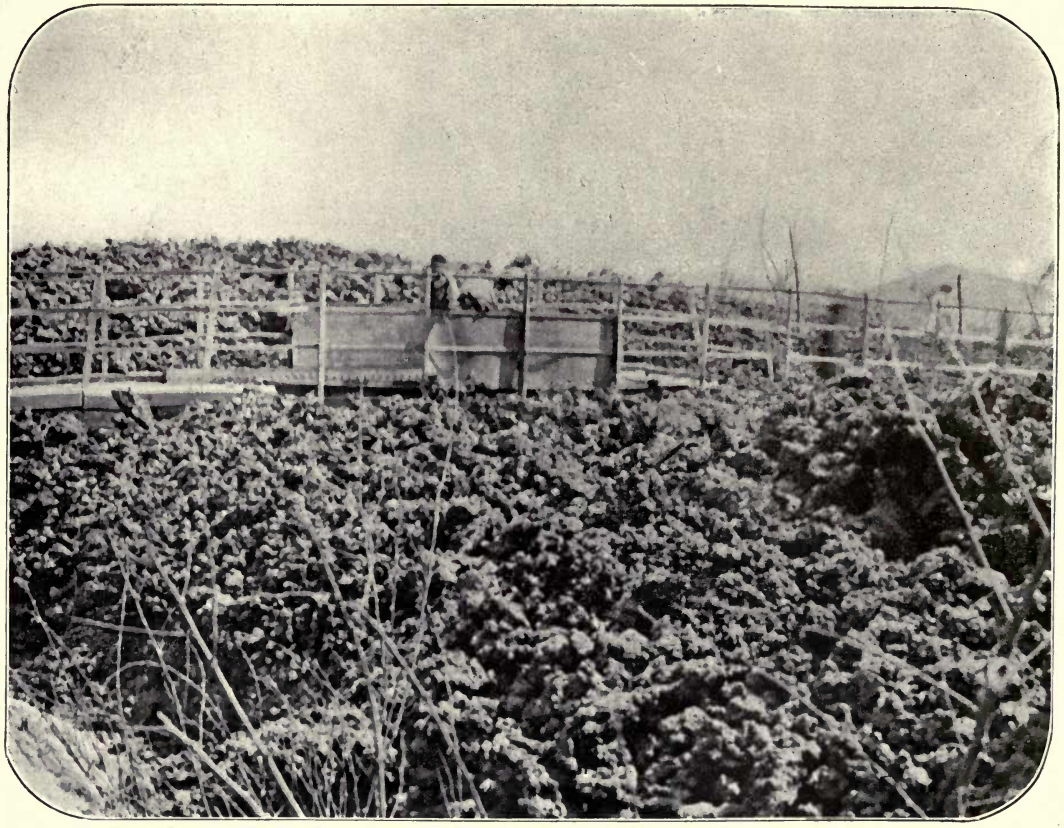

PLATE V.—VESUVIUS. LAVA STREAM UNDER RAILWAY BRIDGE NEAR BOSCOTRECASE.

of decrement had begun, the eruption was still dangerous, and the collapse of the central cone probably made the explosions more intense by obstructing the throat of the volcano. Thus, on the evening of the 8th, a succession of these shot up huge clouds of dust, which rose majestically into the sky to heights of 21,000 or 22,000 feet. The latter assumed the well-known pine-tree shape, "enveloping the ordinary clouds of the atmosphere, across which zigzagged every now and then flashes of lightning, accompanied by a tremendous roar of thunder."

The dust clouds travelled towards the north and north-east, accompanied by showers of mud-laden rain and emanations of sulphur-dioxide. They buried the fertile district of Campania in a grey shroud which, at a distance of nine miles from the crater, was nearly an inch in thickness. The wind on the morning of the 9th veered to the north-east and then the dust descended between Naples and Sorrento, first towards Ischia, then in the direction of Capri, and finally some of it was transported even into Spain. All through the 10th the wind kept in this quarter, so that Torre del Greco was buried under a layer of dust a foot thick and kept in total darkness for two days. But that night the wind again returned to a more southern quarter, and the environs of Naples, together with districts on the northern side, which had already suffered, received another layer of dust.

The result on vegetation was most disastrous, and besides this the fine dust produced asphyxia, distressing to human beings and fatal to many birds, but the greatest danger was due to the

weight of the pall of ashes, which crushed in houses and other buildings as happened at Pompeii in the great eruption of A.D. 79.[1] The lava flows, though locally yet more destructive, affected a smaller area. They burnt up the smaller vegetation, but the "bigger trees, whether struck down or left erect, did not catch fire, and their unsinged leaves and blossoms," when Professor De Lorenzo wrote, "formed a gay canopy over the stream of smoking lava which surrounded them up to a height of 7 or even 10 feet," and was then flowing onwards. Dr. Anderson, with his friend Mr. G. Yeld, reached Naples on the evening of April 19th, and on the 22nd walked from Torre Annunziata by Boscotrecase to Bosco Reale, from which place they drove to San Giuseppe. There the layer of ashes was at least two feet in thickness, and it was much the same at Ottajano, whence the railway took them back to Naples (see Plates III and IV). On the 24th they went to Cook's Hotel by the Observatory on Vesuvius, and the next day reached the summit of the main cone. This had undergone rather considerable changes in height and form since Dr. Anderson's last visit. Prior to the eruption it had gradually risen to a height of 4,367 feet above sea-level; but now, measured by aneroid observa-

[1] Where, however, so far as I have seen it, the material was generally larger, much being from the size of a pea to a cherry, but more cellular. A specimen brought by Dr. Anderson from Ottajano consists mostly of fairly solid bits about the size of a hempseed. Other specimens collected from nearer the summit of the mountain varied from rather less than this to an extremely fine powder. A piece of the lava from near Boscotrecase is a compact darkish-grey rock, with still darker spots, a leucite-tephrite. All of these, as Professor De Lorenzo remarks, agree with the eruptive products of Vesuvius from 1872 to the present day.

PLATE III.—VESUVIUS. BED OF ASH WITH SOLDIERS' CAMP AT ST. GUISEPPE.

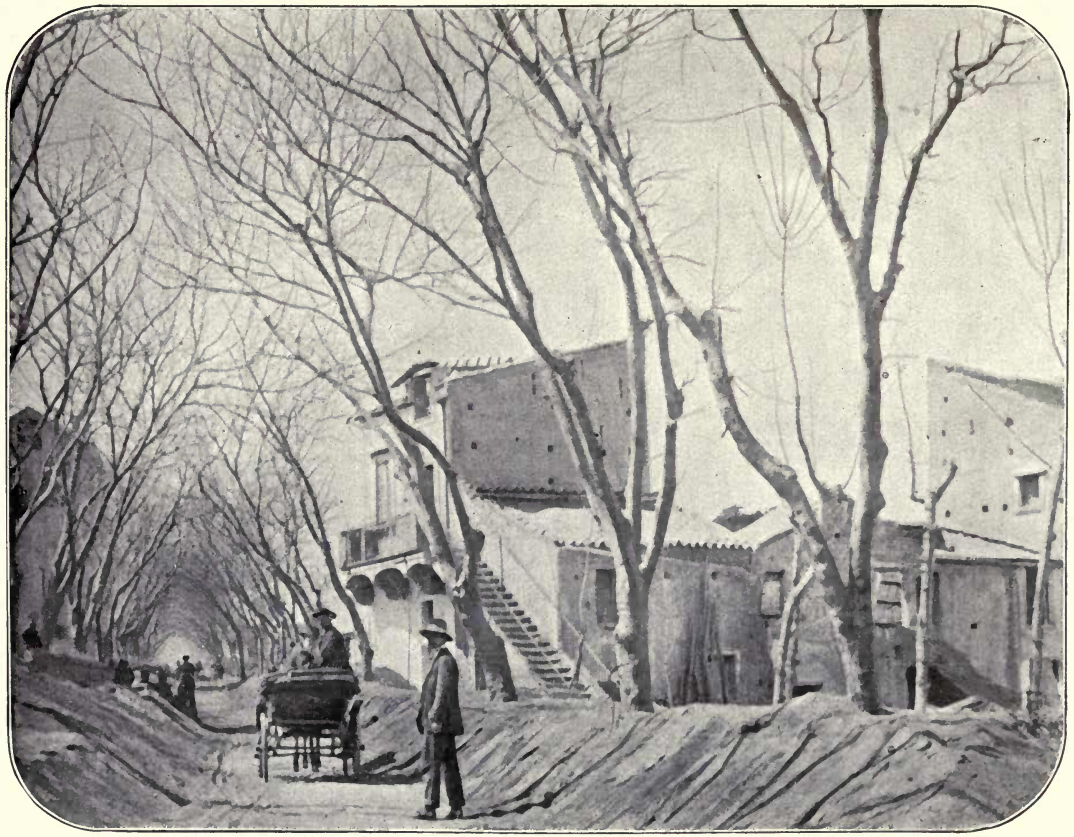

PLATE IV.—VESUVIUS. ROAD FROM ST. GUISEPPE TO OTTAJANO CUT THROUGH ASH.

PLATE I.—VESUVIUS. THE CONE BROKEN BY THE 1906 ERUPTION.

PLATE II.—VESUVIUS. EDGE OF CRATER, APRIL 25, 1906.

tion from the Observatory (1,976 feet), it only attained to 4,050 feet —a loss of over 300 feet in height. The crater was heart-shaped, the broader end, corresponding with the lowest part of the rim, being the northern one; its diameter also had about doubled since 1872 (Plate I). Near to the rim some fumaroles were noticed, rumblings were heard, and clouds of dirty steam occasionally discharged. Plate II shows their first approach to the rim of the crater, when Mr. Yeld was advancing with caution to test its solidity. The 25th was spent in examining the district nearer the Observatory and photographing explosions from the principal cone, and the next day in climbing to the crest of Somma. They made an expedition from Naples up its outer slope, but the muddy condition of this prevented them from getting beyond the highest point visible from that city, and on May 7th they returned to England.

III

THE LIPARI ISLANDS

ALL the Lipari Islands, of which Stromboli is the northernmost, are volcanic in origin. From some the craters have entirely disappeared, and one, Basiluzzo (represented in *Volcanic Studies*, Plate XXVII), is probably a remnant of a great cone shattered by explosions in prehistoric days, but Stromboli and Vulcano, the most northern and the most southern, are still active. Dr. Tempest Anderson visited these islands in 1888, and included in his *Volcanic Studies* eight of the photographs taken on that occasion. Four of them represent Vulcano, which for many years had been quiescent except for some fumaroles which deposited sulphur. But a violent eruption began a few weeks later with very little warning. The manager of the works, who lived with his children in a pleasant villa a few hundred yards from the base of the cone, had to hurry away from it during the night and seek shelter by the seashore in recesses of the crags, for before they could quit their home a hail of stones came rattling down on the roof, two or three of these, a yard in diameter, breaking through into the rooms below. One glowing mass actually fell before them on the floor of the drawing-room as

they opened the door into it in order to pass through to the back of the house. The eruption continued, with intermittence, for at least a year, and Professor Sollas, who in September 1889 spent some days at the islands, was fortunate enough to see a grand outbreak from a hill above the town of Lipari, of which he gives a vivid account in his book entitled *The Age of the Earth* (page 70). Yet two or three days afterwards it had so completely ended that he and his friends were able to gain the edge of the crater and look down upon its floor, without anything to disturb them. Steam was issuing from sundry fumaroles, but that was all. It was quiet, except for five or six fumaroles, in April 1904, when Dr. Anderson and Mr. Yeld visited the island; and when I saw it, in 1908, we spent an hour on the broad lip of the crater, which seemed even more inactive than in his photograph, and I might have walked anywhere on the bottom. In shape it resembled a huge pie dish, with a hollow, like a small pudding basin, in one part of its floor. But we could see from the waste of ash which had buried the low ground to the north, once covered with vineyards, and from the huge blocks which were lying on and at the foot of the cone, that Vulcano—the traditional site of the lame god's forge, and the mouth of hell in some Christian legends—could be terrible in its wrath.

Stromboli is a volcano of quite a different type, one which is hardly ever at rest. To it Dr. Anderson specially devoted himself in 1904, when he was accompanied by Mr. G. Yeld, and twice ascended to its crater. Describing his experiences in an article

PLATE VI.—STROMBOLI. SERRA DI VANCORI.

contributed to the *Geographical Journal* (vol. xxv. p. 123), entitled "Recent Changes in the Crater of Stromboli," he remarks when referring to an excellent description, given by Professor Judd after a visit in September 1874, that since then—

"Stromboli has continued its wonted activity, generally of a moderate character and so regular that it might be called rhythmical, though occasionally varied with periods of violence and sometimes of almost total quiescence. As a result, certain changes have occurred in and about its crater—not on any large scale, it is true, but sufficient to be of interest."

He took photographs in 1888 from selected points of view, and another set in 1904, with the same camera and lenses, in as nearly as possible the same positions, five of which are included this volume.

The island is approximately circular; built up entirely of volcanic ejecta, rising out of water about five hundred fathoms deep, the highest point of it being 3,022 feet above sea-level. This lies on a crescentic wall, the Sierra di Vancori, which is open to the north and like Somma is part of a more ancient crater (see Plate VI). The one now active lies at a height of about 2,400 feet on the opposite side of a flattish valley, which is crossed by the track from St. Vincenzo, the principal village of the island, to Ginostra. This crater, in which is more than one vent, has opened out between two fragments—the Torelle—of the shattered northern wall,[1] at the top of a long slope of volcanic materials, called the

[1] The western Torella is prominent in Plates VIII and IX.

Sciarra, down which ejected blocks roll to the sea after the more violent explosions (*Volcanic Studies*, Plate XXI). In 1888 Dr. Anderson's estimate of the breadth of the principal crater was 60 or 70 yards, but he afterwards thought this to be rather under the mark. The explosions at that time came from a small cone near its western end; the other, at the eastern one, emitting only vapour. By 1904 the hollow of the crater had been filled, and the explosions came from mouths on the slope of the Sciarra (Plate VII), but this change, as he believed, was due rather to the piling up of débris than to an actual shift of the places of discharge, and the relative positions of the two kinds of explosion were the same as in 1888. These, with some subsidiary fumaroles, are shown on Plates IX and X.

Professor Mercalli in the *Atti della Societa Italiana di Scienze Naturali* (vol. xxiv.) gives a list of the more severe outbreaks between 1878 and 1891. He and his companion Professor Ricco, found, in the month of June of the latter year, one large crater, corresponding with that seen by Dr. Anderson in 1888, and four smaller "bocche" on or about its northern edge at the top of the Sciarra. During the last quarter of a century Stromboli has more than once passed through a rather violent phase, as it has done from time to time in the past. For instance, three streams of lava were emitted in June 1891; there were a few bad explosions in 1895 and a very violent one in the following year, which hurled masses of incandescent lava and scoria to great distances and shrouded the whole island in a cloud of dust. Again, the spring

PLATE VII.—STROMBOLI. THE SCIARRA FROM THE NORTH-EAST, 1904.

PLATE VIII.—STROMBOLI. THE CRATER FROM THE WEST, 1904.

PLATE IX.—STROMBOLI. EARLY STAGE OF AN EXPLOSION.

PLATE X.—STROMBOLI. ADVANCED STAGE OF AN EXPLOSION.

of 1899 was a paroxysmal time, and a new mouth opened on the upper edge of the Sciarra, while from March to November in the following year Stromboli was unusually active, the explosions occasionally shaking the whole island and covering it with volcanic dust. Signs of that, or perhaps of some later paroxysms, were visible in 1904 when I passed along the eastern coast on my way from the Strait of Messina to Naples, for the higher vineyards were scorched and partly buried under black dust. In that year Dr. Anderson made the photographs already mentioned. Of these, Plate VII may be compared with Plate XXI of *Volcanic Studies*, for it shows the Sciarra with its fumaroles and an explosion of the ordinary character from a vent just out of sight. Plate VIII gives a view of the crater from the west, while Plates IX and X are of exceptional interest, for they illustrate the same explosion, the one at an early, the other at an advanced stage. It is possible, as Professor Sollas has described in graphic terms (*The Age of the Earth*, page 72), to watch one of these discharges from quite near to the vent; but there is no telling how violent the next outburst may be, and in any case the observer must keep a sharp look-out for falling fragments of the half-cooled lava. One rather large mass actually fell between him and his companion, which now reposes in the Geological Museum of Trinity College, Dublin. I was not so fortunate in 1908, for though I twice ascended the mountain, steam and some cloud made it impossible to see the actual vents and there was not a single explosion on either occasion, though we spent four or five hours on

the summit; nor did I hear one during the three days that I passed on the island. But we were rewarded on the first occasion by seeing our party—three in number—as Brocken spectres over the saddle leading down to St. Vincenzo; and on the second by studying the different kinds of ejecta from comparatively recent eruptions: bombs, solid and hollow, splashes of viscid lava on the surfaces of the rocks, and the black sand on the north-eastern slopes, on which we basked while picking up little crystals of augite.

PLATE XI.—ETNA FROM TAORMINA, APRIL, 1908.

IV

A SHORT OUTBREAK FROM ETNA

I HAD the good luck to witness a small eruption from Etna in April 1908, during a stay at Taormina with Dr. Anderson and his old companion, Mr. G. Yeld, Editor of the *Alpine Journal*, after the former had ruptured, no less unaccountably than unfortunately, an important muscle in his right leg while descending a path from the Monte Venere, whither we had gone in the hope of obtaining a more panoramic view of Etna.[1] The mountain rose in full sight of my bedroom window at the Hôtel Timeo, and on looking out about half-past six on the morning of the 29th I perceived that instead of the thin, sometimes almost imperceptible, white cloud,[2] a considerable mass of darkened steam was being emitted from the summit, and apparently was drifting downwards over the Val del Bove. After carefully watching this I felt almost certain that some discharge must also be occurring near the head of the latter. About half-past nine o'clock,

[1] Two photographs of the volcano, showing a lava stream near Nicolosi and the principal cone (10,850 feet) from the Observatory, are given in *Volcanic Studies* (Plates XVIII, XIX). They were taken in 1888, when Dr. Anderson reached the summit.

[2] Plate XI, taken during this visit, shows the volcano as it ordinarily appeared.

Mr. Yeld and I walked throughTaormina to its southern entrance, where we saw that the quantity of steam issuing from the summit crater was much reduced, for we could often distinguish through it the right-hand slope of the cone, but that a dark smoke-like mass was rising from near the head of the Val del Bove, on its northern side. After we returned to the hotel, I went to the ruined Greco-Roman theatre, and sat on one of the highest parts to watch the volcano. The discharge from the summit had by this time died away into a little white steam, when suddenly, about 10.20 a.m., a mass of cumulus cloud, just like a cauliflower of irregular growth, but dark as one used to see from a factory chimney after the fire had been fed, spouted up suddenly, and then drifted slowly downwards towards the Val del Bove, the vent in which had continued its discharge. In about ten minutes the two clouds had become parallel, but were not quite united, their edges being sharply defined against the blue sky. In a few minutes more the cloud from the summit rapidly became small and white, and by half-past eleven it had practically ceased, but that from the Val del Bove continued to rise, though perhaps in a rather diminished volume. Besides this a small quantity of white steam was being ejected from a spot rather higher up than the main source. In another ten minutes the issue of steam from the summit had almost ceased.

I then returned to the hotel, where I found Dr. Anderson had been carried to a good point of view on the terrace, and we became convinced, after careful watching, that the cloud in the Val del

PLATE XII.—SMOKE DRIFT FROM ETNA; AFTERNOON, APRIL 29, 1908.

Bove was emitted from a fissure rather than a crater, and that débris was falling from it. But about ten minutes after noon another black cloud was ejected from the summit cone, and we heard sounds resembling the firing of distant cannon. Two or three times while at the theatre I had noticed single reports, but had felt uncertain whether they might not have been due to gunnery practice. In a few minutes the two clouds had joined, that just mentioned seeming not quite so dark as the other one, from which some débris evidently was falling, and its smoke almost hid the Val del Bove. The summit cloud then slightly increased in volume and came out in puffs, like that from the funnel of a locomotive, afterwards drifting over the Val del Bove; for though the air was quite calm at Taormina, on the top of Etna there was evidently a slight current from about W.N.W. By half-past twelve this had almost ceased, but below the dark cloud from the Val del Bove a line of whiter steam was visible, rising apparently from the floor of the valley, as if it was coming from an outflow of lava. In a little more than an hour another dark cloud, though not quite so big as before, was ejected from the summit, and white steam rose very distinctly above the dark cloud in the Val del Bove. About this time Dr. Anderson took two or three photographs, though under serious difficulties, since he was unable to move from his couch; of these, Plate XII is one. Later in the afternoon, between half-past four and a quarter past five, portions of the cloud emitted from the Val del Bove became detached, as if floating away, and assumed peculiar forms, some-

thing like ill-made muffins of different sizes. One of these is represented on Plate XIII.

By this time little steam was coming from the summit cone and still less from the Val del Bove. There was no alteration during the remainder of the afternoon, but after sunset a dull glow became perceptible in one part of the Val del Bove, and grew brighter as the darkness increased. Seen through a glass it appeared like a spot or patch, at times slightly elongated, resembling a lump of red-hot iron, with a fainter extension, especially on the right hand, which was perhaps due to reflection on steam. Sometimes also a bright spot could be seen a hundred feet or so higher up the mountain-side, on a line drawn from the larger one at an angle of twenty or twenty-five degrees. No glow was visible lower down the valley, where we had seen the steam supposed to come from flowing lava, or at the summit. We remained on the terrace till after ten o'clock, without observing any further change, and next morning no sign of disturbance was visible, and Etna remained quiet till the afternoon, when I was obliged to quit Taormina and hasten back to England.

Dr. Anderson's notebook contains a number of very brief observations recording the progress of the eruption, taken sometimes at intervals of barely ten minutes. As a transcript of them would occupy rather too much space, it may suffice to say that they confirm my own notes, on which the above account is founded, and that he observed from his bedroom, which also commanded the mountain, some dark smoke issuing from its

PLATE XIII.—ETNA. ISOLATED SMOKE CLOUD, APRIL 29, 1908.

summit so early as half-past five in the morning, and became certain of an outbreak in the Val del Bove at half-past nine. He records on April 30th (on which we left), "mountain pretty quiet." It was hid by haze on May 1, but the next day a broad dark track was visible among the snow in the Val del Bove. A day or two later a new-comer to the hotel, who had reached the Val del Bove over the summit of Etna, informed him he had seen only one *bocca* in the former, which was situated on a fissure about a quarter of a mile in length. The lava stream from it was between a mile and a mile and a half long with an average breadth of about a quarter of a mile, and the explosive force had sufficed to project bits of scoria, as large as nuts, to a distance of some three miles. On May 6th Dr. Anderson states that the wind brought smoke direct from Etna to Taormina, and that he collected a little fine dust from tables on the terrace. The next day he began his journey back to England.

V

THE SOUFRIÈRE IN ST. VINCENT

THE former volume of *Volcanic Studies* was already in type and on the eve of publication when, on May 7th, 1902, the Soufrière broke out into destructive eruption, which was followed next day by one yet more disastrous from Mont Pelée in Martinique. The Royal Society, as speedily as possible, obtained the services of Dr. Tempest Anderson and of Dr. J. S. Flett, Petrologist to the Geological Survey, to examine the results of these abnormal outbreaks, and they arrived in St. Vincent on June 10th. Their investigations appeared as a Joint Memoir in the *Philosophical Transactions of the Royal Society* (A. vol. cc. 1903, pp. 353–553), illustrated by a number of Dr. Anderson's photographs, and he took advantage of the delay in the publication of his own book to add to it three views from St. Vincent and one from Martinique. Nearly five years later, in the spring of 1907, he revisited these islands in order to study the alterations made by the action of tropical rains, and the extent to which vegetation had returned in the devastated regions. The results were published, together with a paper containing Dr. Flett's petrological work on the

specimens collected in 1902, in the *Philosophical Transactions* (A. vol. ccviii. pp. 275–332).

A backbone of volcanic mountains, as mentioned in the above-named volume, occupies the middle and greater part of St. Vincent, of which only the highest and northernmost, the Soufrière (4,048 feet), is active. For ninety years it had been at rest, after a violent eruption in 1812, and a lake had formed in its principal crater. Then, after sundry premonitory earthquake shocks, the outbreak began on May 6th and by evening had increased in strength. During the night and the earlier part of the next day it was obviously becoming more intense. Clouds of steam were shot up from the summit, and torrents of boiling mud came rolling down the main valleys, as the contents of the crater-lake were discharged. Then, just before two o'clock in the afternoon, occurred the terribly sudden climax. A huge black cloud burst out from the summit and swept down its sides to the sea. It consisted of dust, scorching hot; it penetrated into houses, and few of those who inhaled it survived. The air was full of sulphurous fumes; stones, large in the neighbourhood of the mountain, came raining down, and a midnight darkness spread over the island. But these were minor perils compared with that deathful simoon. About 1,600 persons perished, and many more were seriously burnt. The fine dust, as had happened in 1812, was carried as far as Barbados; about 110 miles. The violence of the eruption was at an end by the morning of the 8th, and by the 15th the Soufrière appeared to have again gone to rest.

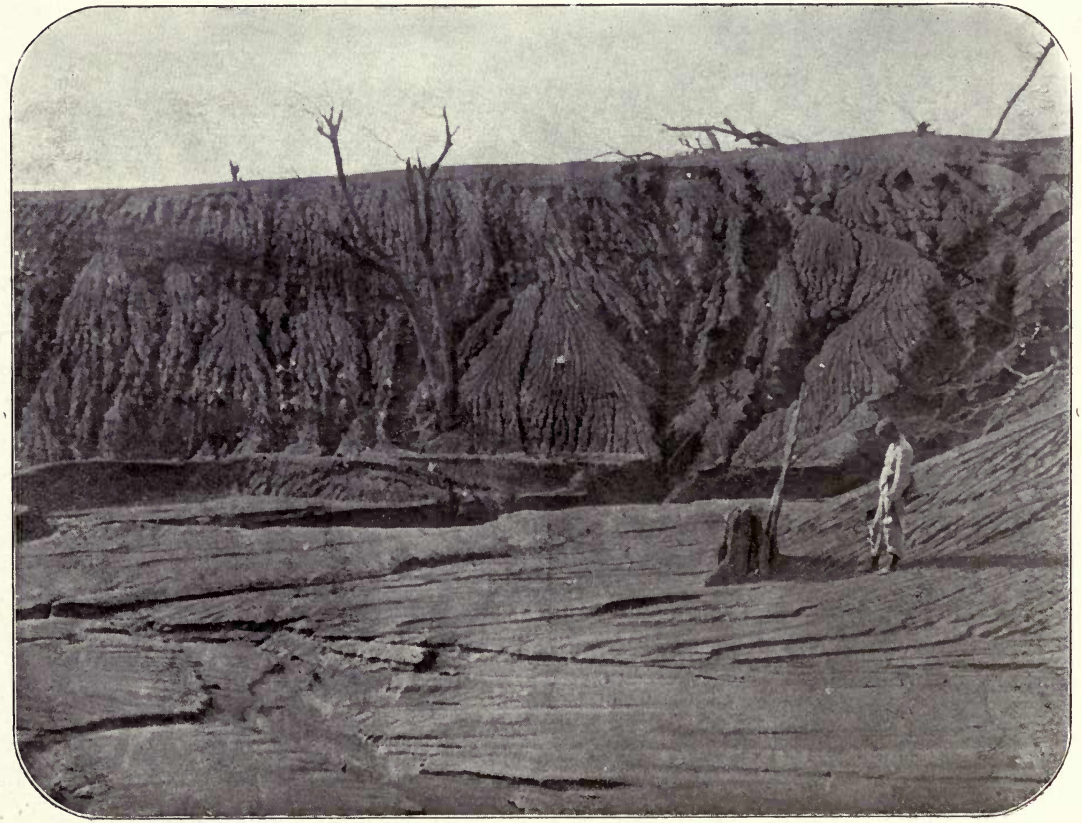

PLATE XIV.—ST. VINCENT. DENUDATION OF ASH, WALLIBU PLANTATION FIELDS.

PLATE XV.—ST. VINCENT. ASH AND DEAD TREES, HIGHER CARIB COUNTRY, BASE OF SOUFRIÈRE.

PLATE XVI.—ST. VINCENT. A SECONDARY CRATER-PIT IN THE ASH.

PLATE XVIII.—ST. VINCENT. DENUDATION ON SOUFRIÈRE, WINDWARD SLOPES.

But there was another outbreak, severe though short in duration, on the 18th. Others occurred in the autumn and in the spring of the next year, when dust again fell in Barbados on October 16th and March 24th.

The heavy tropical rains which had occurred between the May eruption and the visit of Drs. Anderson and Flett had cut deep channels in the mud which had filled the Rabaka and Wallibu valleys.[1] The steeply sloping sides of these channels were furrowed in the usual way, as if they had been scored with a giant's rake. Beneath the surface the mud was still extremely hot, often discharging steam as if from fumaroles, and sometimes ejecting it with explosive violence, so as to form small bowl-shaped craters. These results are illustrated in Plates CII and CIII of the former volume and in Plates XIV, XV, XVI, XVIII of the present one.

Drs. Anderson and Flett twice ascended to the summit of the Soufrière, but the rising steam and drifting mists, usual at that season of the year, prevented them from obtaining satisfactory photographs of the crater. It was then perhaps 1,400 feet deep, and contained three lakes of greenish-tinted water. One of them was boiling vigorously and throwing up jets of steam and mud. An attempt to walk round the edge of the crater was prevented by the depth of mud lodged upon it and by a storm of wind and rain.

In March 1907 Dr. Anderson again visited St. Vincent in

[1] The valleys descending from the Soufrière, especially the Rabaka and the Wallibu, which run in opposite directions from the southern side of the summit.

order to study the further effects of denudation and the return of vegetation. He found that the valleys had been more deeply excavated, their flanks more strongly gashed, the deltas at their mouths much increased in volume (see Plate XIV), while the ash had hardened on the crests of ridges (Plate XVII) but had been swept away from their sides. The ascent to the crater had become less troublesome, and he was able on March 26th to obtain a good view of its interior. Its walls were in most places nearly vertical, formed, as usual, of beds of tuff and of lava, occasionally cut by dykes (Plates XX, XXI). At the bottom was a lake of light-green water, about half a mile in diameter, which no longer boiled. Its walls and outer slopes were bare, except for a few patches of moss; and on the tracts, swept by the hot blast or buried beneath mud and ash, vegetation had begun to return and to clothe the surface, except where this was prevented by the frequent slips. Grass, herbaceous plants, creepers, shrubs, and tree-ferns were luxuriant up to about 1,000 feet above the sea, abundant up to 1,500 feet, but very sparse above that elevation. The change is illustrated by a comparison of Plate XIX with Plate CIV in the former volume.

PLATE XVII.—ST. VINCENT. RIDGES WITH REMNANTS OF ASH ON SOUFRIÈRE.

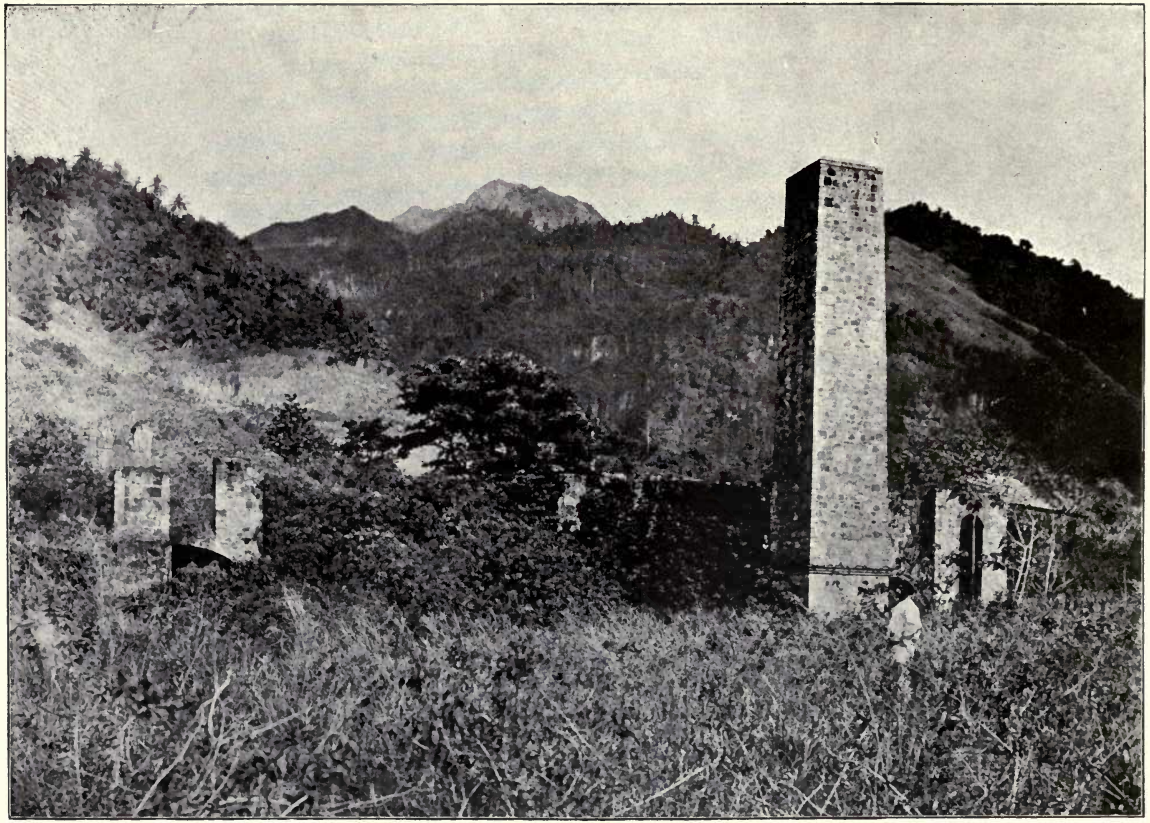

PLATE XIX.—ST. VINCENT. VEGETATION RETURNING, RICHMOND PLANTATION.

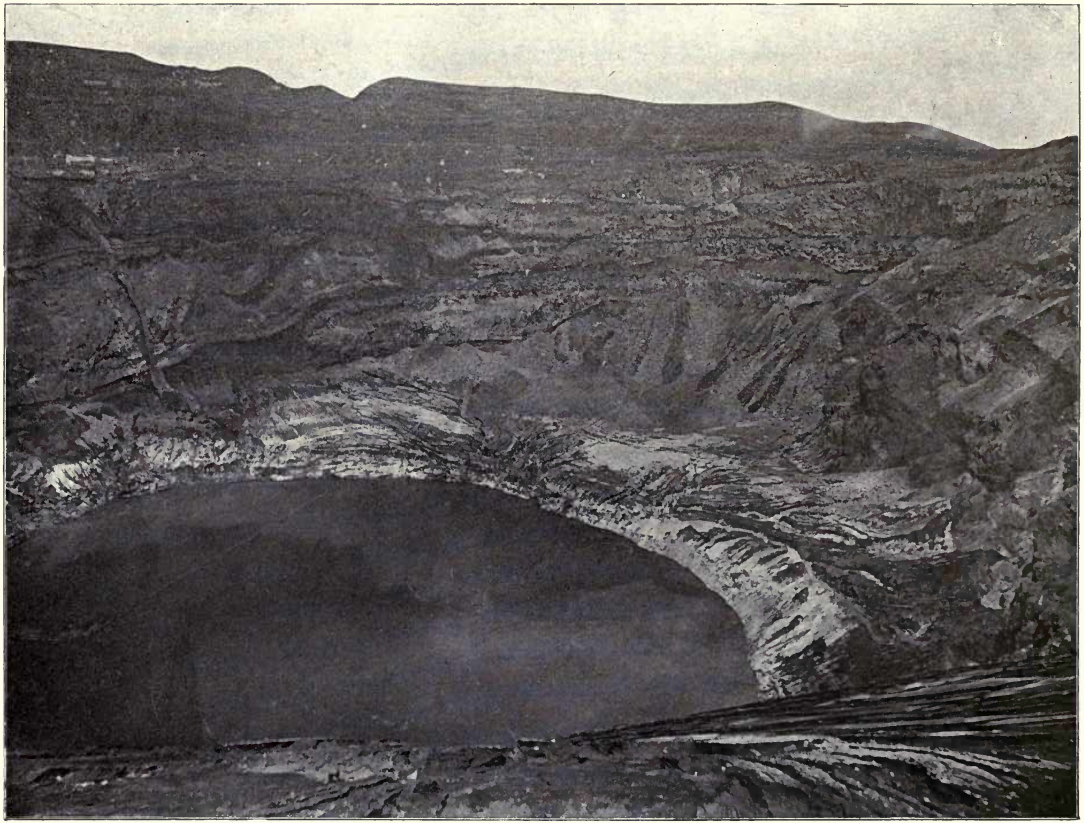

PLATE XX.—ST. VINCENT. CRATER OF SOUFRIÈRE FROM ITS SOUTH-WEST LIP.

PLATE XXI.—ST. VINCENT. CRATER WALL OF SOUFRIÈRE FROM ITS SOUTHERN EDGE.

VI

MONT PELÉE IN MARTINIQUE

THIS volcano rises at the north-west end of Martinique, and like the Soufrière is seamed with deep ravines. It is rather the higher, being 4,428 feet above the sea. On the summit was formerly a small crater, surrounded by a serrate range of cliffs about 200 feet in height, but there were several parasitic cones, the sources of vapours and hot springs. A short but not severe eruption occurred in 1851, the only one recorded in history. On the lowest slope of the mountain stood St. Pierre, a flourishing sea-port with nearly 30,000 inhabitants. About April 23rd in 1902 steam was seen ascending from the crater, and by the evening of May 2nd a bright gleam became visible over the mountain-top, loud noises were heard, dust and ashes fell during the night on St. Pierre and the neighbouring country. On the 5th a flood of mud rushed down the Rivière Blanche, a valley reaching the sea about half a league north of the town. This activity increased, the discharges of steam becoming more violent, the detonations louder, and the fall of ashes heavier; but nothing exceptional occurred on May 7th, the fatal day for St. Vincent. "But on the

following morning the great convulsion came and with it the end of all things for St. Pierre."

The top of Mont Pelée seemed to split: a huge cloud, glowing at its source but quickly blackening, swept down with a mighty blast upon the doomed city, when the streets were thronged with people, many of them, as it was Ascension Day, on their way to the churches. The houses in its path were shattered, the vessels in the harbour destroyed; one only, the *Roddam*, escaping, for it had but just arrived and had steam up, though some of the crew were killed and all severely scorched. A suburb of St. Pierre alone escaped, for it lay outside the path of the dust avalanche; the rest was a burning ruin, and in a few minutes about 28,000 people were dead or dying in agony. Fires broke out in many parts, thus adding to the completeness of the destruction, and later eruptions, on May 20th and 28th, and on June 6th, increased the thickness of the pall of débris. But the amount ejected from Mont Pelée was much less than that from the Soufrière on the preceding day; here also the incandescent cloud had but one outlet, the fissure on the crater wall, and though the surrounding region was devastated, no lives were lost outside its path. But of the ruin done within it Plate XXIII may suffice to give an idea.

[1] As related in the *Philosophical Transactions* (A. vol. cc.), it would have been impossible to reach the crater; indeed Dr. Anderson and Dr. Flett had a narrow escape from an outburst on the evening of July 9th (slightly different in direction) like that which had destroyed St. Pierre. A representation of this eruption in an earlier stage is the last plate in *Volcanic Studies* (1903).

PLATE XXIII.—MARTINIQUE. STREET VIEW IN ST. PIERRE.

PLATE XXII.—MARTINIQUE. CRATER OF MONT PELÉE MARCH 13, 1907.

In the interval between Dr. Anderson's two visits Mont Pelée had exhibited a very singular phenomenon.[1]

"First, as far as can be ascertained, a dome-like mass of lava formed in the crater, from the middle of which a kind of tower or 'spine' of similar material was protruded. It made its first appearance during the night of November 3rd and grew at an average rate of about 33 feet a day till the 24th, when its height is given as 761 feet (5,167 feet above the sea). Then it began to decrease, not by sinking down, but from the constant breaking away of large fragments, till its height was diminished by almost 500 feet. On February 7th, 1903, a new, though less rapid, period of protrusion began, and by July 4th it had reached 1,969 feet above the old crater-lake, or 5,276 feet above the sea; and then it gradually collapsed, till at the time of Dr. Anderson's visit only a stump of it was left in the middle of a heap of ruins." [1]

Plate XXII shows this stump rising as a dark boss on the right-hand side, and beyond it is part of the wall of the crater, seen through the drifting clouds. It was the clearest view Dr. Anderson could obtain, though he twice ascended the mountain. Underneath the stump, in the lower part of the photograph, part of the cone of talus, manifestly formed out of its ruins, is visible, and at the junction of the two something may be seen of a "ring of very active fumaroles, from which steam and other vapour was escaping with a loud roar, obviously under considerable pressure."

[1] From T. G. Bonney, *Volcanoes*, p. 49. The account is condensed from the fine memoir, published by Professor A. Lacroix, entitled *La Montagne Pelée, etc.*, in which is an excellent view of the "spine."

The return of vegetation in Martinique was very similar to what had been observed in St. Vincent. On the east side of Mont Pelée, practically all the trees at a height of 1,500 feet were killed, and their trunks remained as bare stumps, but a luxuriant vegetation was growing up, chiefly from the old roots. Large sheets of ferns were particularly noticeable. These plants extended considerably higher up—to about 2,000 feet—where they gave way to grasses, while towards the summit only a few mosses and lichens were found. The ruins of the houses in St. Pierre were embedded in ash and covered by a dense jungle of tropical vegetation. But the valley of the Rivière Blanche and the district between it and the town were still bare, probably because they had been repeatedly swept by those scorching clouds.

VII

SOME MEXICAN VOLCANOES

LATE in the summer of 1906 Dr. Anderson left England for Mexico to attend a meeting of the International Geological Congress in its capital city and to visit some of its volcanoes. To the latter he devoted a few weeks after taking part in that meeting and one or two of the subsequent excursions. The journey, however, was less successful than usual, in consequence partly of the difficulties of travel in a country where civilisation had not extended very far from the main lines of communication, and partly of an illness, due to ptomaine poisoning, from which he recovered rather slowly.

The Mexican volcanoes mostly rise, like those of the Ecuadorian Andes, from an elevated central plateau some seven or eight thousand feet above sea-level,[1] and the majority of them are extinct. As Dr. Anderson's course could not easily be followed without a map, and as its main aim was to enter the country from the Atlantic and leave it by the Pacific coast in order to follow that to Guatemala, it will be a simpler plan to take the volcanoes, not as they were visited, but first on the eastern, then

[1] The altitude of Mexico City is 7,432 feet.

on the western side of the capital. Of the former group, Orizaba, which the Aztecs called by a name meaning the Star Mountain, is remarkable not only for its altitude—about 18,200 feet, which makes it one of the highest in North America—but also for the regularity and symmetry of its form. Apparently no photograph was taken of it, though it is not unfrequently mentioned in Dr. Anderson's notebook, perhaps because he was never quite near enough to obtain an effective one. At the summit are three craters, separated by ridges of lapilli, and its flanks are studded by small cinder cones and craters. The ascent, as we are informed by the late Professor Heilprin, presents no real difficulty and the tree line stops at about 12,000 feet. The summit commands a fine view over the great table-land of Central Mexico and of the twin giants Iztaccihuatl and Popocatepetl, the summits of which are barely ten miles apart. The former, or the White Woman, to translate the Aztec name, is 17,318 feet high, and its snow-clad summit, from which some glaciers descend, is well shown on Plate XXIV. Three points on the crater rim, the bowl of which is largely filled by snow and ice, differ but little in altitude, and the ascent to this might sometimes present considerable difficulties to inexperienced travellers.[1]

Popocatepetl, which reaches 17,816 feet and once enjoyed the reputation of being the highest mountain in North America, is conical in its general outline and terminates in a large crater, on

[1] An ascent by Mr. H. R. Whitehouse is described in the *Alpine Journal*, vol. xv. p. 268.

PLATE XXIV.—MEXICO. VIEW OF IZTACCIHUATL.

PLATE XXV.—MEXICO. POPOCATEPETL FROM NEAR FLAMACAS.

the rim of which two points rise rather above the rest, and this crater, according to Mr. H. R. Whitehouse[1] is more than 1,500 feet in depth and some 2,000 feet in breadth. Though no eruption is on record, the volcanic forces are not yet extinct, for fumaroles discharge steam and deposit sulphur. The quantity of this has created a local industry, which is perhaps the most elevated in the world, about fifty tons being annually collected. Mr. Whitehouse gives a striking description of the crater : " Great jets of roaring, hissing steam shoot up in twenty or thirty places, depositing layers of pure sulphur and melting the snow for yards around them. Avalanches of rock and ice are constantly falling on all sides." In his opinion, Iztaccihuatl is much the finer mountain of the two, for it looks like the Grand Combin, while Popocatepetl is only a white cone. In the view from the latter, Orizaba, a perfect sugar-loaf, towers up a hundred miles away.

The fates were against Dr. Anderson in his attempt to reach the summit of Popocatepetl. After passing an uncomfortable night in a dirty hut[2] between 12,000, and 13,000 feet above sea-level, where he was conscious of some difficulty in breathing, he left by starlight with a companion and guides, and presently watched the rising sun illuminate Iztaccihuatl and the distant cone of Orizaba. All went well till they came to the foot of the permanent snow slope. This, as a rule, presents no difficulty,

[1] See a description in the *Alpine Journal*, vol. xiv. p. 403.

[2] Plate XXV was taken, so far as can be ascertained, on the way to this place.

but its surface was at that time so hard that it would have been necessary to cut steps for the remainder of the ascent—about 1,800 feet. The guides objected to the labour. Dr. Anderson's companion had no nails in his boots, and was obliged to be back in the city on the following day, so that he had to abandon the excursion and was apparently prevented by rising clouds from taking satisfactory photographs.

Xinantecatl—the Naked Lord—also called the Nevado de Toluca, is an extinct volcano which has undergone considerable denudation. It rises to a height of almost 15,000 feet some forty miles to the south-west of Mexico City. Dr. Anderson ascended it on November 8th, having passed the previous night in a small and very much ventilated log-hut. Above this he was able to ride for a considerable distance along a fairly good path, and gained the summit without any difficulty. On this, however, clouds began to gather not long after he started, which prevented him from obtaining good photographs, though they disclosed at intervals parts of the crater rim. On its floor, nearly a thousand feet below the highest portion of this rim, are three lakes, the two smaller separated from the larger one by a dome-like mass of lava, and no doubt indicating the last effort of the volcanic energy, the cone itself being built up of beds of scoria and intercalated lava flows. Plate XXVI shows this and the walls of the crater through the floating mists. The underlying slopes of scree proves denudation to be in active progress, and Plate XXVII, which was probably taken on the journey from the inn

PLATE XXVI.—MEXICO. XINANTECATL (NEVADO DI TOLUCA).

PLATE XXVII.—MEXICO. APPROACH TO XINANTECATL.

PLATE XXVIII.—MEXICO. DISTANT VIEW OF COLIMA.

PLATE XXIX.—MEXICO. PART OF COLIMA.

PLATE XXX.—MEXICO. THE SUMMIT CRATER OF COLIMA.

at Calimaya to the sleeping-place, affords similar evidence.[1] No eruption is recorded in Mexican history.

The volcano Colima, which is still active, rises, some forty miles from the Pacific coast, to a height of about 5,500 feet and is well seen from the town of the same name. Dr. Anderson visited it from Zapotlan, a town to the north of it, by riding over a group of ridges which sometimes afforded fine views of the mountain. Three have been reproduced, the exact positions of which are difficult to identify, but Plate XXVIII must have been taken at no great distance from Zapotlan, Plate XXX from a position much nearer to the mountain, and Plate XXIX from one comparatively close, probably representing an outlying fragment of the original crater. This, according to Dr. Anderson, forms a Somma ring within which rises a smaller and a larger crater, both intermittently active. At the foot of this ring is a hut, which, after he had put up a small tent within it, provided him with fairly comfortable quarters. The first day was spent in visiting the craters, the larger of which apparently rises some distance from and at a higher level than the smaller one. Here they lingered long enough (he had with him a Mexican companion and a porter) to be overtaken by darkness on some crags, where, though they could communicate with their camp by shouting, they had to pass the night. Cold and their

[1] An expedition to this mountain was organised for members of the above-mentioned Congress, an account of which is given in the *Geological Magazine* (1907, p. 5) by Mr. B. Hobson.

cramped position made that a very uncomfortable one; sleep was almost impossible, and though they returned to shelter about half-past six the next morning, most of the day had to be devoted to rest. On the following one, which was also spent in working about the craters, they witnessed an explosion which ejected steam and volcanic dust. These were carried by the wind to a considerable distance, and afterwards produced some fine atmospheric effects. On the next morning they began their return to Zapotlan, obtaining from one of the ridges a distant view of an explosion.

VIII

THE NEW CRATER OF SANTA MARIA WITH OTHER VOLCANOES IN GUATEMALA

THE volcanoes of Guatemala form a row of cones averaging from 10,000 feet to 12,000 feet in height, roughly parallel with the Pacific coast. They rise from a hilly platform about 5,000 feet above the sea, which descends, at first rather steeply, to the lowland fringe so that they can be seen from a passing vessel in their full elevation. Coffee plantations or tropical forest clothe both fringe and upland. As a rule the volcanoes are quiet for many years, one of them now and then breaking out with great violence, rarely discharging lava, but ejecting huge quantities of fragmentary material, which devastates large areas of the surrounding country. They have some parasitic cones, usually on the Pacific Ocean side, but to this rule Cerro Quemado and Santa Maria are exceptions.[1]

The former of these volcanoes, 10,436 feet in height, rises near to the town of Quezaltenango. It has been inactive, except for

[1] Dr. Anderson described his visit in January 1907 to this part of Guatemala in a communication to the Royal Geographical Society, which is published, with illustrations from his photographs, in the *Geographical Journal*, vol. xxxi. (1908), p. 473.

a small outbreak in 1891, since 1785, when it discharged enormous quantities of lava, which consolidated on unusually steep slopes and often terminated in vertical walls, perhaps 100 feet high, proving that it must have been emitted in a rather "pasty" condition. In its crater, which is small and breached on the north side, Dr. Anderson found several breadcrust bombs,[1] a fine example of which is represented on Plate XXXI. Such bombs, as he observes, occur, among other places, at Vulcano in the Lipari Islands and on Colima in Mexico. Their peculiar structure is not easily explained. Obviously it is due to strains, set up by contraction in the crust after it has formed, and I think that if the still molten interior happened to contain a larger than usual quantity of water-vapour, this, when excluded during cooling, would contract more rapidly than the cellular mass by which it was enclosed, and thus subject the ill-supported crust to a severer strain than if the bomb had contracted more uniformly in all parts, like a metal casting.

Dr. Anderson also ascended Atitlan, 11,570 feet, some thirty-five miles south-east of Cerro Quemado. Forests clothe the slope, but at last give place to reddish scoria and pumice. At the top he found only a shallow and rather ill-defined crater with some fumaroles, emitting, so far as he could see, steam only. It looks down on a beautiful lake, twenty miles in length,

[1] So called because the cracks on their surfaces resemble those in the crust of certain kinds of bread.

PLATE XXXI.—GUATEMALA. BREAD-CRUST BOMB IN CRATER OF CERRO QUEMADO.

PLATE XXXII.—GUATEMALA. CLOUDS ON ATITLAN.

PLATE XXXIII.—GUATEMALA. SANTA MARIA FROM THE SLOPES OF CERRO QUEMADO.

and he was led to think from the aspect of the sides of this, particularly in one important part, that possibly it might occupy a portion of an ancient crater. In that case this would be one of the largest, if not the largest, in the world. The mountain itself is represented on Plate XXXII.

The volcano of Santa Maria lies a few miles to the south of the Cerro Quemado, and appears from that point of view to be a remarkably regular cone (Plate XXXIII). It was supposed to be extinct, until the noted lateral outburst which occurred in October 1902. This, however, appears to have only partially destroyed the rich vegetation on its more northern slopes. On the actual summit, which is 11,480 feet above sea-level, is a small crater, forming an irregular, shallow, rocky depression some 120 feet in diameter. The new crater opened out near the base of the great cone, on a little shelf about 6,000 feet above sea-level, and the eruption which formed it began on October 24th. Slight local earthquakes preceded the outburst, and about five o'clock in the afternoon an increasingly loud sound, like a boiler blowing off steam, was heard in a neighbouring village, apparently from the direction of Santa Maria. A light sprinkling of sand then began to fall, which gradually became more abundant and presently reached a place six miles to the south-west. About seven o'clock in the evening a glow began to appear, roaring sounds to be heard, and lightnings to be noticed in the neighbourhood of the present crater. An hour later the air had become clear enough to allow people at a distance to perceive, above this site,

an enormous black cloud. It was seamed with countless curved lines of electric discharges, while violent claps of thunder were heard. During the early hours of the next morning, stones, an inch in diameter, began to fall frequently on the neighbouring district, some of which were projected as far as Quezaltenango, ten miles away to the north-north-east. The darkness became more intense as the eruption increased in violence, and it culminated rather before midday on the 25th, though it continued to be severe until nightfall. The air, indeed, did not begin to clear, or the light to return, till about the same time next day, but the eruption lasted, with varying severity, for six days more.

A new crater was then found to have been formed near the base of the great cone of Santa Maria, the whole surrounding country having been devasted and covered deeply with ashes. This crater, which Dr. Anderson visited early in January, 1907, is oval in shape: its longer axis, which lies parallel with the coast, measuring rather more than three-quarters of a mile, its shorter one somewhat exceeding half a mile; its depth was apparently from about 1,000 to 1,500 feet, and a lake occupied the bottom. In its walls Dr. Anderson observed many outcropping beds of tuff and agglomerate, but could not identity any of lava. Above the crater the side of the mountain had been blown away, exposing a section several thousand feet in height. The photographs reproduced on Plates XXXIV to XXXVI illustrate in each case the shattered flank of the

PLATE XXXIV.—GUATEMALA. SHATTERED CONE OF SANTA MARIA.

PLATE XXXV.—GUATEMALA. THE NEW CRATER, SANTA MARIA.

PLATE XXXVI.—GUATEMALA. THE NEW CRATER, SANTA MARIA.
FROM ABOVE BATHS OF SABINA.

old cone,[1] two showing the walls of the new crater, already furrowed by the tropical rains. The dead tree trunks in the foreground of Plate XXXVI give some idea of the devastation caused by the outburst. Near to the crater the ejected material must have been at least 100 feet in depth, and occasionally perhaps almost double that amount. At the foot of the mountain it was often thirty to forty feet, and some miles away varied from five to ten feet. The valleys near the former position were to a great extent, if not wholly, filled up, so as to produce a general smoothness of the ground. The erosive effect of swollen streams and rain rivulets on the new material was practically identical with that which Dr. Anderson had already noted in St. Vincent (see Plates XV and XVII). The top crust had been removed from some places where the ash had fallen but thinly, so that here the mountain shoulder was often reduced to a rather narrow ridge.

Two facts indicate the violence of the more severe phase in this eruption: one, that the height to which the clouds of steam and ash were shot up into the air was estimated, from the deck of a vessel passing along the coast, to be seventeen or eighteen miles; the other that the finer dust was carried as far as Acapulco in Mexico, a distance of some 600 miles to the north-west. The sound, however, travelled in the opposite direction, being heard

[1] A similar origin, by lateral explosions, was attributed to the Val del Bove on Etna by Sir Charles Lyell. See *Principles of Geology*, ch. xxvi. vol. ii. p. 18, Twelfth Edition.

at Punta Arenas in Costa Rica, which is at much the same distance. Here the reports were at first mistaken for the guns of a warship, supposed to be firing on the other side of a headland which obstructed the view in that direction. At the great eruption of Krakatau the fine dust, the air waves, and the sound waves travelled much farther, as will presently be described, but the special characteristic of the Santa Maria outburst was the formation of so great a crater well down the flank of an apparently extinct volcano—an occurrence, however, to which more than one parallel can be found.

IX

TARAWERA IN NEW ZEALAND

A VISIT to New Zealand was the first stage in Dr. Anderson's journey of 1909, but as the pocket-book with his memoranda unfortunately cannot be found, I am unable to trace his exact route or to ascertain the precise localities of one or two of his photographs. But they represent the district which, about thirty years ago, was the scene of a destructive eruption, by which New Zealand was deprived of a natural wonder. A volcanic belt, about 160 miles in length and 35 miles in breadth, runs from White Island in the Bay of Plenty diagonally across the North Island to Tongairo near its south-western coast. This belt abounds in crater-cones, mud volcanoes, fumaroles, geysers, and hot springs. It is also noted for the beauty of its lakes, some small, and occupying craters, others of larger size and different origin, but all formerly bordered by primæval forests—a district once a stronghold of the Maoris, and afterwards a favourite resort of visitors. About the middle of the belt, a short distance from the eastern shore of Lake Tarawera, stands a commanding eminence, which also bears that name. Prior to 1886 it was a rather flattened dome, about three miles in length and half a mile in breadth,

rising abruptly from a fairly elevated plateau—undoubtedly a volcanic mass, but one which had suffered much from denudation, for its top was without a crater. Its highest point, Ruawahia, was 3,609 feet above the sea; its southern one was called Tarawera by the natives, but the name of late years has been extended to the whole mass. To the north of, and slightly separated from them, was a third summit, called Wahanga.

Soon after midnight on June 10th, 1886, earthquake shocks began. Slight at first, they increased in strength till, at a quarter past one—

"Wahanga broke out with a vivid flash of light, followed by loud explosions; only a small cloud was seen, which appears to have subsided, and all was again quiet. At 1.45 a.m. the main eruption commenced with a roar from Ruawahia, and a black column, glowing with reflections from red-hot rocks below, shot upwards. At 2.10 a.m. a violent earthquake occurred, and Tarawera (proper) exploded with a deafening noise, sending up a broad steam column. At 2.30 the whole mountain-top from Tarawera to Wahanga was apparently on fire, throwing out immense columns of red-hot scoria."[1]

At much the same time great quantities of steam were emitted from some craters two or three miles away to the southward. About half-past three earthquake shocks began again, and lasted

[1] Quoted from a description of the eruption of Mount Tarawera by Captain F. W. Hutton in the *Quarterly Journal of the Geological Society* (London) for 1887, p. 178, from which most of the facts in this article have been taken. Use has also been made of a valuable paper by Dr. J. M. Bell, *Geographical Journal*, xxvii. (1906) p. 369.

till six o'clock, and then Rotomahana exploded, throwing up a huge volume of steam and volcanic dust, though without any showers of red-hot scoria.

"The sounds now were frightful; even at Rotorua, fifteen miles distant, it was necessary to shout as loud as possible in order to be heard two yards off. Mixed with the deafening roar of escaping steam were loud explosions from underground, and long rolls of thunder from above, as well as a hissing sound, caused by the solid particles in the air rubbing together."

The whole country, for a considerable distance round, was covered first with mud and then, over a more limited area, with a fine white ash. The two were as much as ten feet deep at the township of Wairoa, on Lake Tarawera, half-way between Rotorua and the volcano Tarawera.[1] These violent explosions, however, seemed to give relief to the pent-up volcanic forces, which began to be less effective about half-past five and had almost ceased in about twenty-four hours, though the more distant group of craters, already mentioned, continued to discharge steam for some weeks afterwards.

During this eruption the beautiful Lake district of New Zealand lost one of its greatest attractions, the Rotomahana Terraces, so named from a small lake of that name two or three miles south of Tarawera, which was surrounded by numerous fumaroles and hot springs. Both were formed of siliceous sinter,

[1] R. Etheridge, *Geological Magazine*, 1886, p. 400.

deposited from the hot water, as happens with the geysers of Iceland and of the Yellowstone Park. The White Terraces, rather the larger and more noted of the two groups, both of which were on the western shore, had their origin in a hot spring—the Terata geyser—which spouted up from a crater-like hollow about a hundred feet above the lake. From this they descended the slope, spreading out like a fan, till they encroached a little on the margin of the water in a wide sweep about 800 feet in length.[1] They formed a succession of shallow basins and steps, thus affording a series of warm baths where the visitor could select one the temperature of which was to his liking. These terraces were shattered—utterly destroyed—in the great outburst which followed the eruption from Mount Tarawera. With them also perished the Pink Terraces, as they were called from their colour, which was due to the presence of metallic oxides—mostly iron—deposited with the sinter. They were about a quarter of a mile farther south, on the same side of Lake Rotomahana, and were a little smaller than the White Terraces. In fact, Lake Rotomahana was replaced by an enlarged basin, with precipitous walls, and a bottom covered with mud, in which were several circular holes either emitting steam or filled with water.

The three summits of the Tarawera *massif*, the basin of Rotomahana, and a series of small craters to the south-west of it, were evidently formed along an old fissure, about nine miles in length

[1] The description is condensed from one given by Mr. J. Martin in the *Quarterly Journal of the Geological Society* (London), 1907, p. 165.

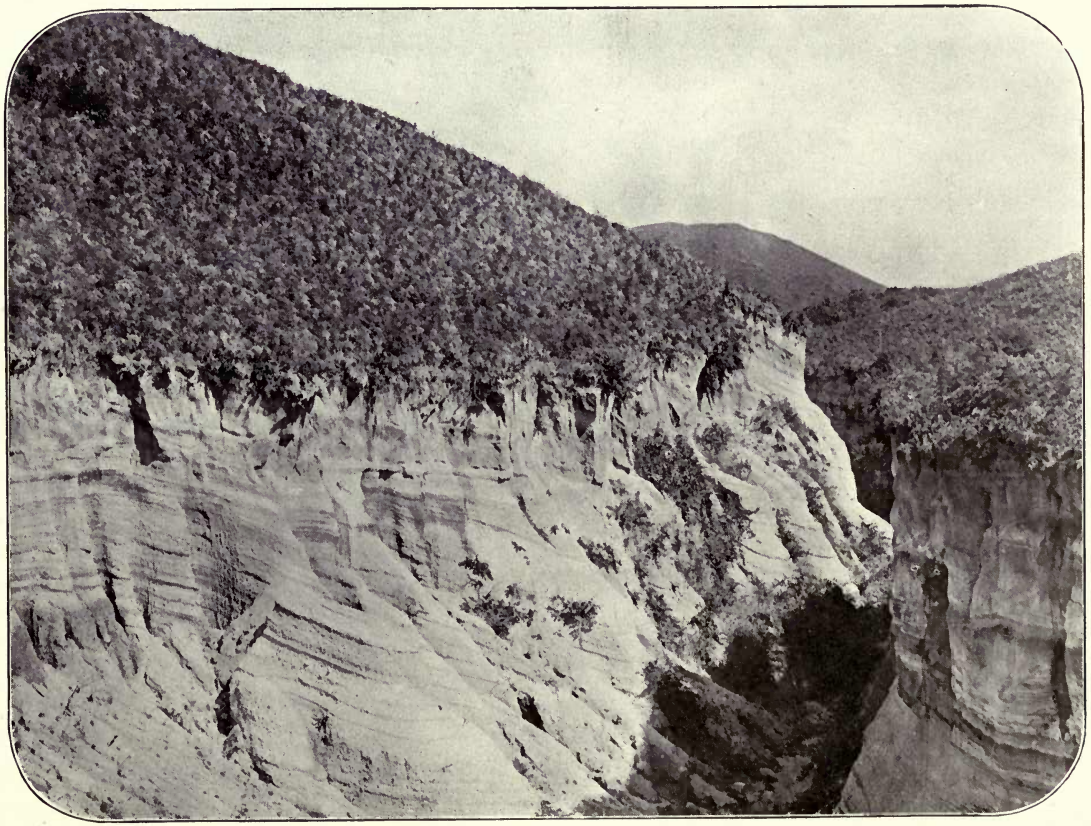

PLATE XXXVII.—NEW ZEALAND. FISSURE FROM EARTHQUAKE, WAIROA.

with a general trend from east-north-east to west-south-west. This appears to have been reopened, especially in its more northern part, in the eruption of 1886, with the results which have just been described. It split the crest of Tarawera, making apparently a small angle with the direction of the old crack, and enlarged the Rotomahana basin. The water of the lake was engulfed at an early stage of the eruption, and no doubt increased, as at Krakatau, the violence of the explosions. Its floor appears to have been occupied at first by wet mud and occasional pools of water, but the latter has now much extended and covered a large part, though it seems still to be divided, by a blockage in the middle, into two parts, the northern one, an addition to the old crater, being called Lake Rotomakariri. This newer fissure runs in places through the district between Wairoa and the above-named line of craters, and Plate XXXVII, from near that township, shows it cutting across a wooded hill-side so as to form a rather conspicuous feature in the scenery.

In 1890 this strange region added a new though rather temporary wonder to its other attractions. This was the geyser of Waimangu, which was discovered in January 1890. Previous to this date it was probably quite inconspicuous, but it then became very active, ejecting mud together with boulders and—

"huge columns of dirty black water vertically into the air. At some hundreds of feet above the water the column broke into a cauliflower-like mass, surrounded by clouds of steam, which showered the boulders, mud, and sand back into the pool and

even high up on the walls which surrounded it. The highest shot is supposed to have ascended to a height of 1,500 feet above the water, and to have carried a volume of 800 tons."

This great geyser suddenly ceased in July 1904, and remained at rest for fifty-four days, then again burst into action, and until November 1st of the same year almost daily outbreaks occurred. Then it stopped, and up to the present there has been no further explosive activity. The whole explosion usually lasted about forty seconds.[1]

As stated above, it is difficult to identify precisely some of Dr. Anderson's photographs, but they illustrate the general character of this volcanic region. Plate XXXVIII illustrates the action of rain and streamlets on the mud and ash ejected during the eruption of 1886, very probably on or near the site of one of the group of terraces. Plates XLI and XL represent geysers, the former at work somewhere on the upland, the latter very probably on the floor of Rotomahana Lake beneath its newly scarped margin, and Plate XXXIX also shows a hot spring, which rises in a pit-like hollow.

[1] Dr. J. M. Bell, *ut supra*, p. 379.

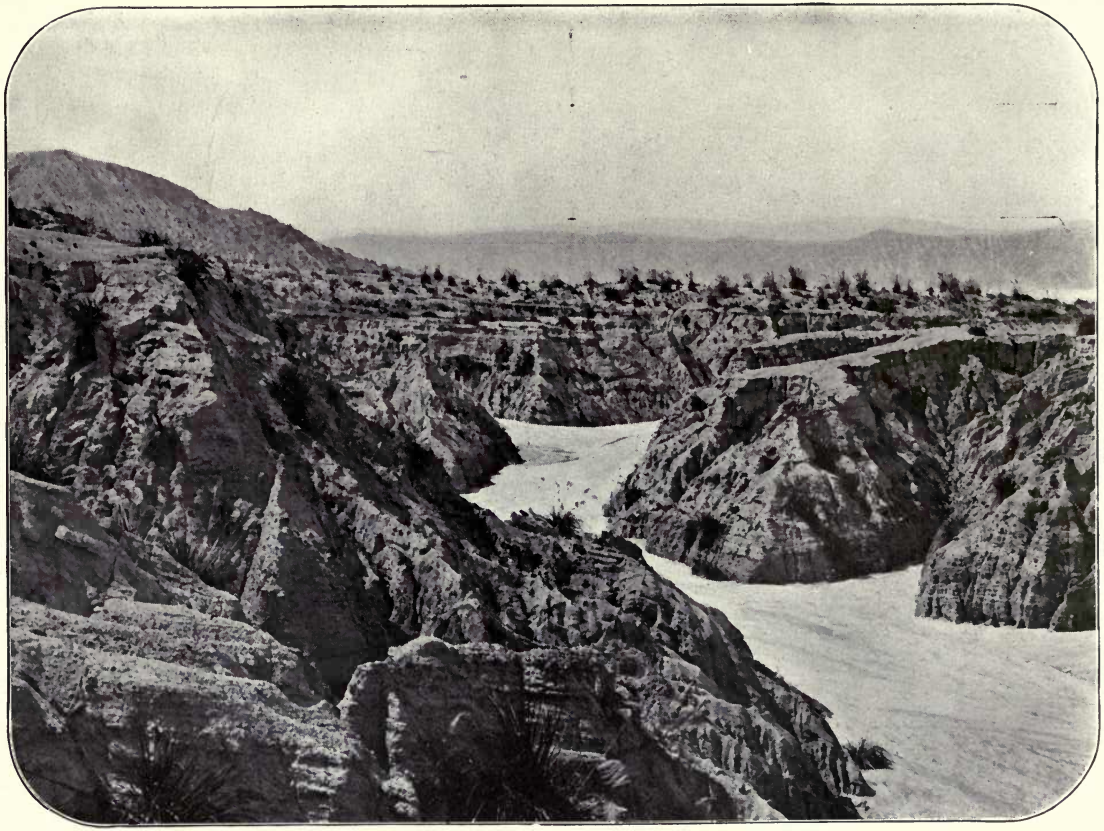

PLATE XXXVIII.—NEW ZEALAND. EROSION OF ASH FROM TARAWERA ERUPTION.

PLATE XXXIX.—NEW ZEALAND. A HOT SPRING ABOVE ROTOMAHANA

PLATE XL.—NEW ZEALAND. A GEYSER BY ROTOMAHANA.

PLATE XLI.—NEW ZEALAND. A GEYSER ON THE UPLAND.

X

MATAVANU IN SAVAII[1]

THE Samoan Islands are a group in the Western Pacific, between 12½° and 14° of south latitude and 168° to 173° west longitude. Nine in number, besides sundry scattered rocks and islets, they lie in a linear direction from north-west to south-east, and are all, with one exception, volcanic. This direction, if prolonged, passes through the Tonga Islands, Pylstaart, and White Island to New Zealand, thus probably indicating the existence of a crack in the earth's crust. Savaii is the westernmost and largest of the group, for it is forty-eight miles in length and not less than twenty-four miles in breadth. Volcanic mountains form its backbone, the highest of which, Mauga Loa, rises to a height of about 5,000 feet. Another of them, Mauga Afi, seven or eight miles to the west, has been the source of most of the extensive lava streams in the western part of the island. One of these, according to tradition, destroyed a native town some 150 or 200 years ago. The lava floods reached the sea and are more extensive and

[1] Dr. Anderson described his examination of Matavanu in a paper published, with several illustrations, by the Geological Society of London in 1910 (*Quart. Journ. Geol. Soc.*, vol. lxvi. p. 620), the substance of which is given in this article.

more rugged in character than those of 1905. An eruption from a small crater, some two miles to the north-east, discharged three years previously a stream of scoriaceous basalt about as many miles in length, and more to the east is a large crater-lake called Mauga Pule, from which most of the flows of lava to the east of the island have issued. The site of the eruption which began in 1905 was rather to the north of this, and at a lower level, about 2,000 feet above the sea, on a sort of elevated plain surrounded by mountains. From this place, Matavanu, a deep and tortuous valley, about eleven miles in length, extended down to the sea, which, however, is not more than seven miles away in a straight line. This valley in its lower part was very fertile, and prosperous villages stood on either side of its mouth. The coast was partly formed by crags of old lava, partly protected by coral reefs.

The eruption began on August 4th, 1905, the discharges at first being limited in extent and mostly consisting of ashes, but on September 2nd lava commenced flowing and continued to do this, more or less steadily, until November 3rd. Then the side of the crater broke down, and the lava streamed forth in greater volume till, on December 7th, it reached the sea. Into this it poured and began to fill up the space between the shore and the reef. A marked increase in activity occurred between January 28th, 1906, and the middle of February, with the result that the shore line in one place was advanced to the reef, but at the foot of the crags the change was slight, since the lava fell over them into deeper water. Observers noticed that a surface

crust soon formed on the streams of molten material, beneath which the liquid lava continued to flow. Even at the crater itself the latter seldom poured over the lip, but generally entered openings in the side and took an underground course. Thus the lava field became honeycombed with channels of liquid or pasty material, which occasionally forced its way to the surface and flooded it with fresh sheets. Sometimes it would lift up the crust bodily, or sometimes run away from beneath it and leave a hollow space. The total length of the sea front covered at different times by lava was about nine miles, while the greatest breadth of the flows inland from west to east was not less than fifteen miles.

In 1909 Dr. Anderson spent a few weeks in Savaii, where he carefully studied these lava fields, approaching as nearly as was possible to the places where the liquid material was still flowing and visiting the crater from which it was issuing. He also examined the devasted area in the neighbourhood of the coast and watched the glowing streams as they plunged into the sea. Four times he had a view of them by night from the deck of a vessel, and it was truly wonderful.

" The glare from the incandescent lava in the crater reflected on the clouds is visible for a distance of fifty miles or more, while, on nearer approach the spectacle of a number of streams of red-hot lava descending into the sea and raising columns of illuminated vapour is very remarkable."

By day the crater is seen rising to a height of 2,000 feet, with

a backing of mountains, double that height, and with several old cones of different ages dotted around. From it rises a magnificent canopy of white steam in the well-known pine-tree shape, often breaking into the no less familiar cauliflower lobes. This discharge frequently rose to an altitude of 8,000 or 10,000 feet.

The cone is not very much higher than the surrounding lava-field, at the most hardly more than 350 feet. The crater is oval in shape, the longer diameter being apparently about 400 yards, the shorter one about half that amount. It is occupied by a lake of lava, perhaps 300 yards long and 100 broad, which is so liquid that it constantly beats in surging waves against the walls, where splashes maintain their heat and brilliant colour for some time.

" The surface is in a constant state of ebullition, though not always to the same degree in different parts. Some of the boilings rise in veritable fountains of incandescent liquid basalt of ten, twenty, or even, I think, possibly at times fifty feet high. The whole mass of the lava is at a brilliant white heat, visible as such even in bright sunlight, but a darker scum is continually forming on the surface, especially when the trade wind blows strongly on it. These pieces of scum, like ice-floes, break up and flow down to the north-eastern end of the crater, where they and the liquid lava disappear down a hole, or rather tunnel, at the foot of the cliff. The tunnel is perhaps thirty feet wide. Its roof is quite low, and is nearly touched by the surface of the lava, which rushes under it at a steep slope with the velocity of a cataract. There is also another smaller hole at the foot of a cliff forming the north-western wall of the crater, down which

PLATE XLII.—SAVAII. CRATER OF MATAVANU, WESTERN END.

PLATE XLIII.—SAVAII. CRATER OF MATAVANU, SOUTHERN WALL.

a stream of lava seems constantly to flow; but this is small in comparison with the other. . . . At the south-western end of the crater is also a tunnel, larger and higher than that by which the lava escapes on the north-east. Its interior is incandescent, and its floor occupied by liquid lava. I am not at all sure that any lava goes out or comes in through it. The whole bottom of the crater is, in fact, in such a turmoil, the lava boiling and surging up, first in one place, then in another, that it is impossible to say definitely where the exact point of entrance is. On the whole, I am inclined to think that it is mainly towards the south-western end, in front of the entrance to the south-western tunnel. . . . The surface of the cone is mostly composed of a series of flows of basaltic lava, similar in type to that which forms the fields around. A considerable number of bombs or ejected blocks of lava of similar character are scattered over the surface; but beyond this the evidences of explosive action, at any rate in the later stages, are very few. In the earlier stages the action appears to have been more of the explosive type" (Plates XLII and XLIII).

On the low ground the lava spread itself out like a fan, and by successive flows at different times covered the coast for a distance of nine miles, destroying four villages, and the town of Saleaula (except two houses), filling up the shallow sea till it reached the reef, and pouring over the cliffs into the deeper water at their foot. Trees close to, and actually in, the lava were killed, and Dr. Anderson observed many moulds where it had solidified round the trunk, which had been burnt out or had subsequently decayed. In the villages the native houses, since

they were flimsy structures of straw and poles, had altogether disappeared; but the churches of two of them, being substantial stone buildings, still remained, for the lava was fluid enough to surround and more or less bury them without overthrowing the walls. In one case near the edge of the flow it poured in through the windows and covered the floor to a depth of several feet (Plate XLIV); in the other the body of the church was hidden under thirty or forty feet of lava, and the only part left visible was the tower, which projected above the upper crust of the solidified stream.

The surface of the lava field varies in character, being sometimes rough and "clinker"-like, sometimes smooth and corded.[1] In places it is flooded by fresh sheets of lava an inch or less thick, or honeycombed by channels along which the liquid material has flowed. These are sometimes open, sometimes covered by a crust. This may be so thin as to give way if any one accidentally sets foot on it. Caves and bubbles of all sizes, up to many feet in diameter, are seen, of which also the roof may be so thin as to be liable to collapse. Now and again extensive areas occur, where the liquid lava, after forming a crust at top, has found a vent at a lower level, and the crust has dropped down as at Thingvalla in Iceland (Plate XLV). The molten material, at the time of Dr. Anderson's visit, was still flowing into the sea

[1] Many geologists, apparently attracted by strange words, have borrowed names for these two world-wide forms of lava from the natives of the Hawaian Islands and call the one *aa* and the other *pahoehoe*.

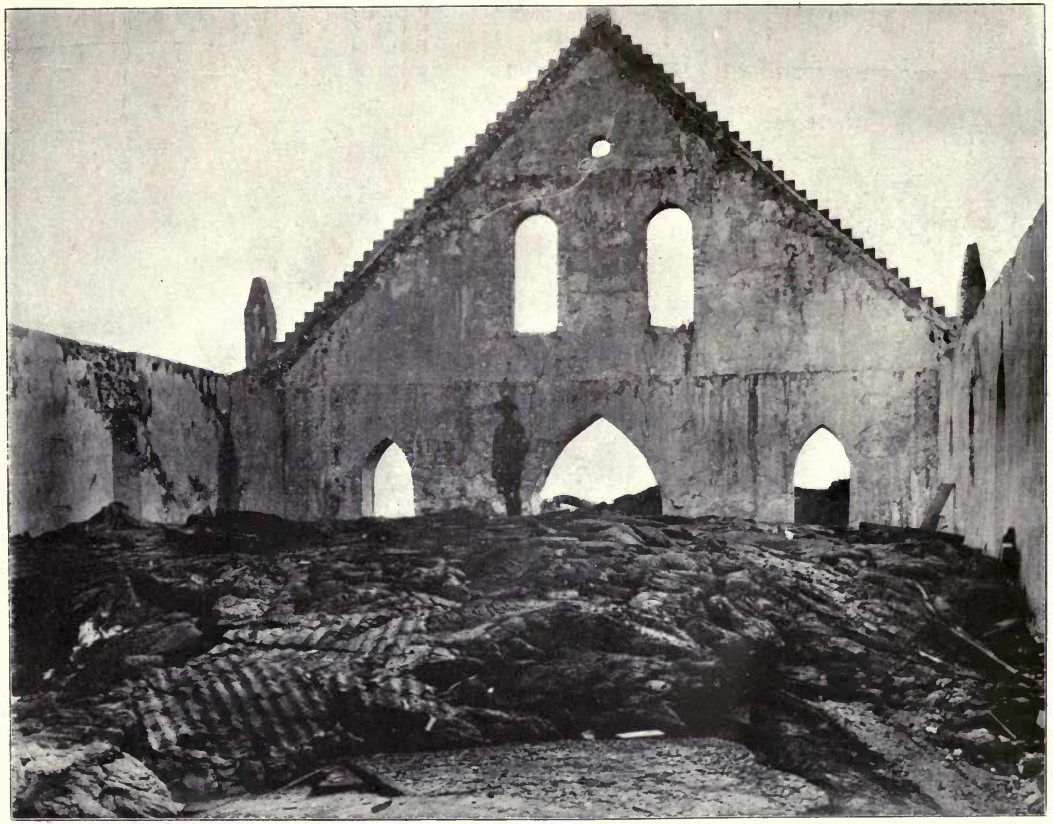

PLATE XLIV.—SAVAII. SALEAULA CHURCH FLOODED BY LAVA.

PLATE XLV.—SAVAII. SUBSIDENCE AND TUNNEL IN LAVA FROM MATAVANU

PLATE XLVI.—SAVAII. EXPLOSIONS OF STEAM FROM MATAVANU LAVA.

PLATE XLVII.—SAVAII. THE STEAM-CLOUD AT ASUISUI;
HOT LAVA IN THE FOREGROUND.

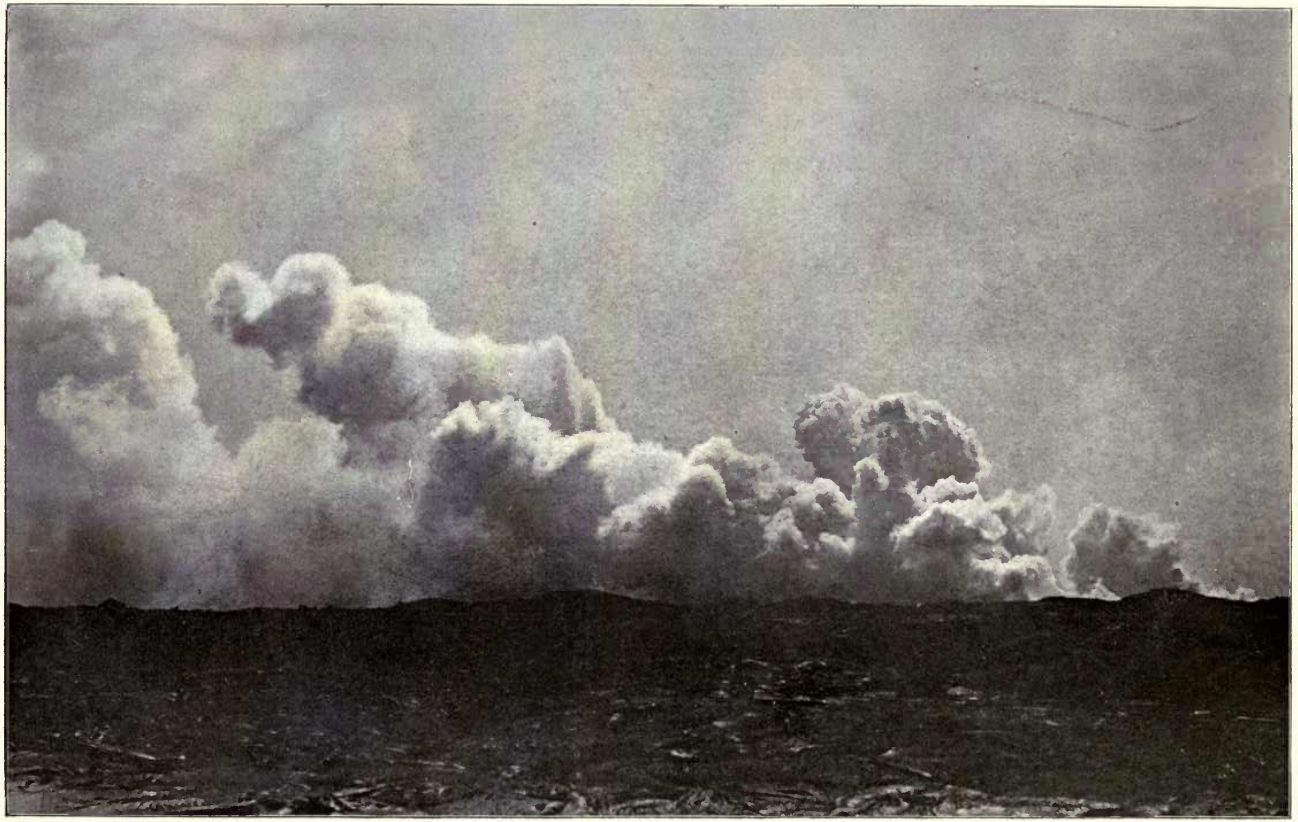

PLATE XLVIII.—SAVAII. STEAM DISCHARGED AS THE LAVA STREAM (SEEN IN FOREGROUND) FLOWS INTO THE SEA.

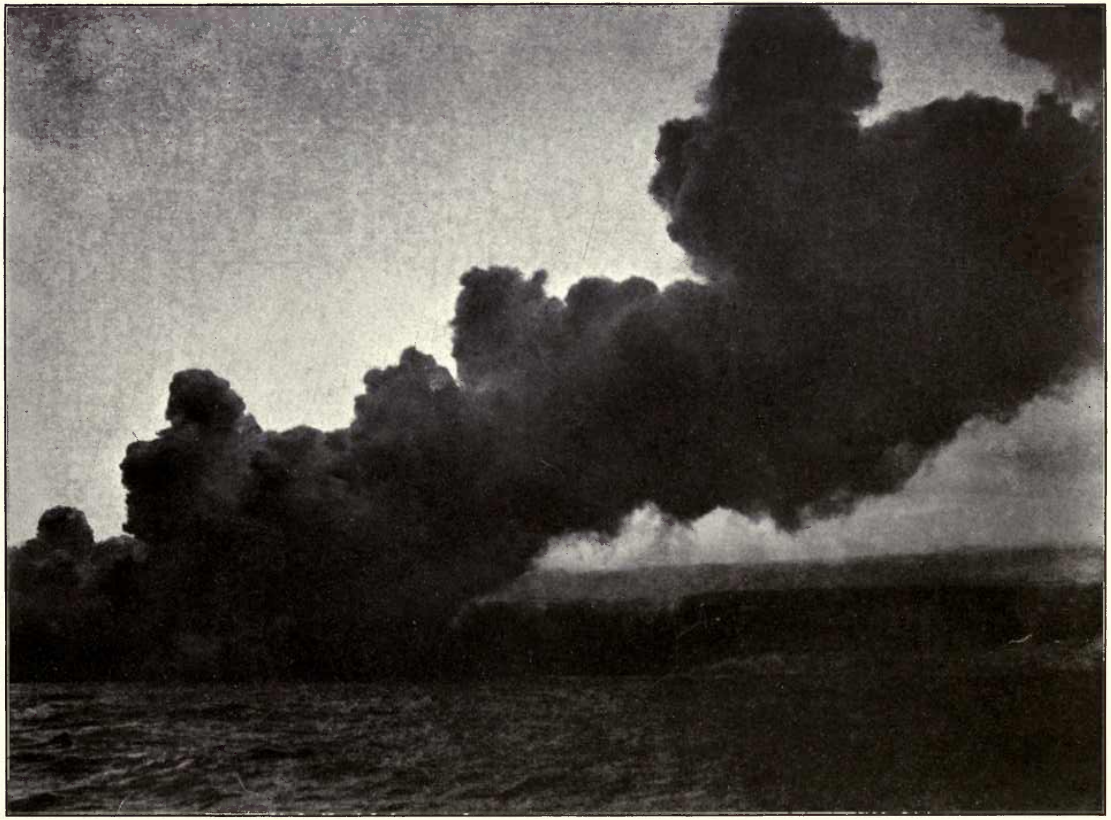

PLATE XLIX.—SAVAII. EXPLOSIONS AS MATAVANU LAVA FALLS INTO THE SEA.

at some places, from which clouds of steam were shot up into the air (Plates XLVI, XLVII, and XLVIII). These places he examined from a boat, since he found it impossible to get a good view of them from the land. This, however, gave him an opportunity of studying the forms which the lava had assumed on being rapidly cooled by contact with the water. When the discharges were more active, explosions were almost continuous, and the whole was obscured by clouds of steam (Plate XLIX) from which fragments of red-hot lava and showers of black sand were seen to fall. When the lava was flowing in smaller quantities, explosions were much less frequent, and it extended itself, as its surface cooled, into buds or lobes with a narrow neck, like a prickly pear, one of which would rapidly increase in size, till it became—

" a lobe as large as a sack or pillow, or perhaps stopped short at the size of an Indian club or a large Florence flask. Sometimes the neck supplying a new lobe would be several feet long and as thick as a man's arm, before it expanded into a full-sized lobe; more commonly it would be shorter, so that the fresh-formed lobes were heaped together. They looked white-hot, even in daylight; and as the waves washed over them, the water seemed to fall off unaltered without boiling, owing probably to its being in the spheroidal condition."

Dr. Anderson states that he had watched the formation of " corded lava " on Vesuvius by a similar process of budding, but there the surface was slowly cooled, while here the whole of it seemed to be chilled at once, as the waves rolled on and off,

and examination of cooled specimens between high and low water-mark at the edge of the lava in the lagoon confirmed this. " The surface at and below the water-level was roughly granular, like that of air-chilled bombs, such as I have seen on Stromboli and Haleakala (Hawaii), while higher up the ordinary corded structure was seen." The pillow lava, with this variation in its outer surface, is illustrated on Plate L, where a native is seated on one of its lobes.

PLATE L.—SAVAII. PILLOW-LAVA BY LAGOON.

XI

KILAUEA IN HAWAII

HAWAII is the chief and southernmost of the group which is now named from it, but was formerly called the Sandwich Islands. They are wholly volcanic, with the exception of some little coral reefs here and there fringing a beach. They rise from the bed of the Pacific Ocean, which at a distance of from thirty to fifty miles is 14,000 to 19,000 feet beneath the surface of the water. Thus, as their culminating summits, Mauna Loa and Mauna Kea, in Hawaii, both exceed 13,500 feet, it is almost certain that a mountain range, little less than 30,000 feet at its highest, has been built up wholly of volcanic materials. The subaerial slopes of these two mountains are comparatively gentle, and this is true of the other islands. They apparently mark the position of a great fissure (or possibly a pair of fissures, for they seem to occur in doublets) in the earth's crust, which runs roughly from north-west to south-east. Kilauea, the crater of which is about 4,100 feet above the sea, is by some authors regarded as merely a huge parasite of Mauna Loa; but as it is twenty miles away, separated from the chief slope of the other

by a depression, and its eruptions are not contemporary, it may claim to rank as an independent volcano.

The crater is unusually large, for its circumference amounts to fifteen or sixteen miles, but is shallow for its size. Compared with one of the usual kind, it is rather a cauldron of lava, commonly frozen over in most parts, which at times rises till it threatens to overflow and then falls again, marking any pause by a terrace on its walls. In form it is a rather irregular oval, the longer axis lying roughly from south-west to north-east, with an extension (called Kilauea Iki) on its eastern side.

The first stranger to visit Kilauea after the discovery of the islands in 1776 was the Rev. W. Ellis (an English missionary) in 1823. Then it could only be approached by paths through the luxuriant vegetation; now Volcano House, an hotel almost on the brink of the crater, is accessible from Hilo by a carriage road. Dr. Anderson spent some days there in 1910, and an observatory has been established near it in charge of his American friend, Professor Jaggar. Many descriptions of Kilauea have been published, the most elaborate being those by Professor Dana, who twice visited the volcano—in 1840 and 1887—and by Captain C. E. Dutton, who made a careful survey of it and the principal volcanoes of the Hawaian group in 1882. At that time the lava floor in Kilauea was about 600 feet below the edge of the cauldron, and in it were two pools of molten lava. The larger of these, which is called Halemaumau, lies nearer to the south-western end, and can, like the other, be examined without serious

PLATE LI.—HAWAII. THE FLOOR OF HALEMAUMAU.

PLATE LII.—HAWAII. CORDED LAVA IN THE CRATER OF KILAUEA.

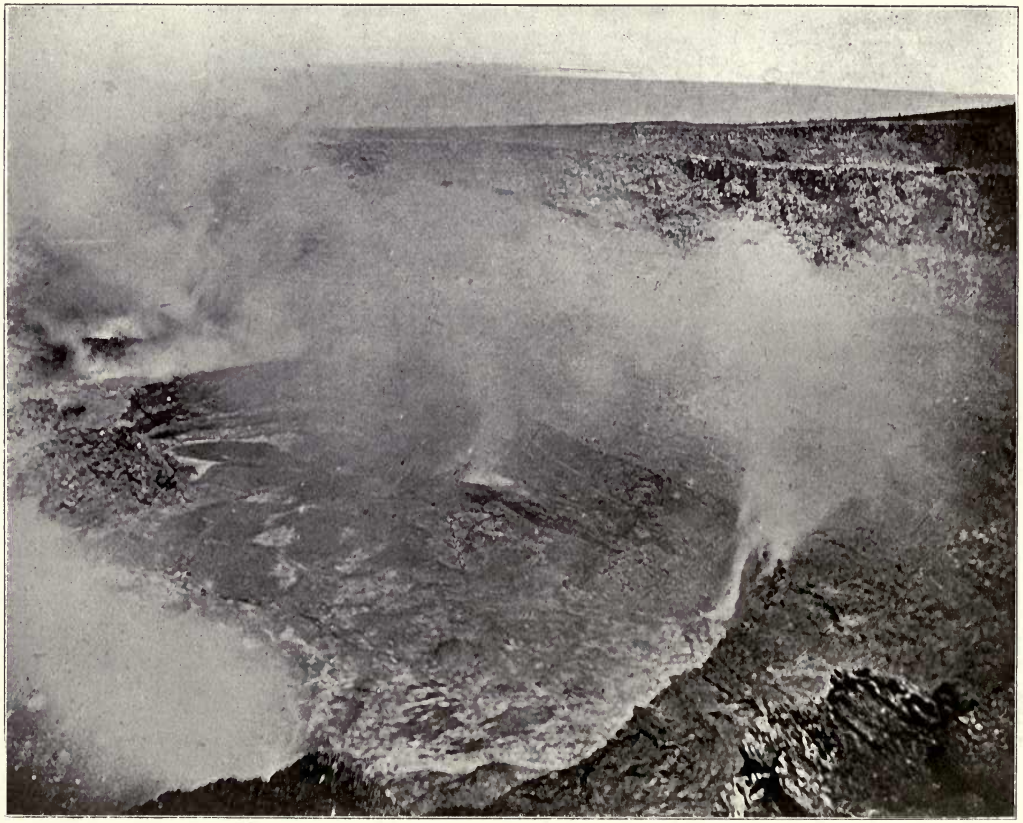

PLATE LIII.—HAWAII. A VIEW INTO KILAUEA.

PLATE LIV.—HAWAII.—ON THE FLOOR OF KILAUEA.

PLATE LV.—HAWAII. FLOOR OF KILAUEA AT NIGHT.

difficulty. It is about a thousand feet in length and nearly six hundred in breadth and is generally rather more active than the other, which is called the New Lake, and is about half a mile away (Plate LI). In each of these a large part of the surface is usually covered with a black crust, which is constantly cracking and locally breaking up, to be engulfed in the seething mass below. This surges up through the fissures, sometimes jetting out in fountains almost white-hot, occasionally to a height of several feet. These basins of molten lava are surrounded by low mounds which rise slightly above the nearly level floor of the cauldron. The solid lava is mainly of the corded type (Plate LII), from which the local name *pahoehoe* has been adopted, but its surface is often very vesicular, and this enables the first-formed crust to float, but the clinker-like or *aa* type may sometimes be found. No great quantity of steam rises, as a rule, from this seething-pot of the nether world, so that good views of the great crater can generally be obtained (Plates LIII and LIV). These, though then much less extensive, are seldom more impressive than at night, when the glowing fluid gleams out from the cracks in the crust of Halemaumau. Plate LV shows perhaps the most interesting of Dr. Anderson's photographs of Kilauea, a night view of that crater taken by its own light.

Kilauea, like most of the other volcanoes in the Hawaian Islands, consists mainly of lava with no great amount of fragmental material, so that flows of the former must have been

more common and generally of greater volume in ancient than in recent times. Eruptions, though the "pot" is always more or less "on the boil," are less frequent than from its giant neighbour Mauna Loa, and the one during which the greatest volume of lava was visibly discharged, since Europeans have lived in the island, began on May 30th, 1840. Unfortunately the Rev. T. M. Coan, the only well-educated inhabitant, was then absent from the island, but he returned in time to witness the later phases of the eruption. According to native accounts the lava surged up in the great cauldron of Kilauea till it threatened to overflow. Then it began slowly to subside. Presently it broke out in four or five places on the eastern slopes of the mountain, one of them being a small parasitic cone about five miles away, and finally, twenty-seven miles away from Kilauea, it poured forth to the light of day at a height of 1,244 feet above the sea. Towards this it flowed steadily, now following a course rather towards the north-east, sweeping away forests, and destroying vegetation, till at last, after a subaerial journey of eleven miles, it plunged into the ocean—

"with loud detonations. The burning lava, on meeting the waters, was shivered like melted glass into millions of particles, which were thrown up in clouds that darkened the sky and fell like a storm of hail over the surrounding country. The light was 'visible for over a hundred miles at sea, and at the distance of forty miles fine print could be read at midnight.'" [1]

[1] J. D. Dana, *Characteristics of Volcanoes* (1890), p. 63.

Mauna Loa not only rises to a much greater height—13,900 feet—than Kilauea, but also has on its summit a yet grander cauldron. The floor of this too is cracked, and its lava fountains are said to play up to a height not much less than 600 feet. Its eruptions are also rather more frequent—on an average about once in every eight years—and lava streams issue from its flanks more often than from those of Kilauea. In an eruption which began on November 5th, 1880, and lasted till August 10th in the following year, three lava streams were emitted from orifices on a long fissure about 11,100 feet above sea-level on the more northern side of the mountain, facing Mauna Kea.[1] Two of them stopped on the higher ground after running from ten to twelve miles; the third and easternmost, which began its course a little later than the others, "came near giving Hilo a burial." Flowing quickly at first, it attained in four months a length of about twenty-six miles; in eight and a half months it was only about two miles from Hilo, and on August 10th, or nine months after the issue began, it stopped suddenly within three-quarters of a mile from the town, so that its whole extent was rather more than thirty-two miles. The stream, in the lower part of its course, followed that of a river, and in two places[2] poured over steps in its bed and substituted a cascade of lava, which froze

[1] J. D. Dana, *ut supra*, p. 204.

[2] The one is about three miles, the other about two and a half miles above Hilo. Dr. Anderson does not record which of the two is represented by his negative.

as it fell, for one of water (see Plate LVI). The greater part of this stream, as the illustration shows, consists of corded lava, but towards the end it assumes rather rapidly the clinker type, for the latter indicates a more slowly flowing and thus a less liquid condition than the former.

PLATE LVI.—HAWAII. CASCADE IN LAVA STREAM FROM MAUNA LOA.

PLATE LVII.—JAVA. VIEW OF GUNTUR FROM LAKE LELES.

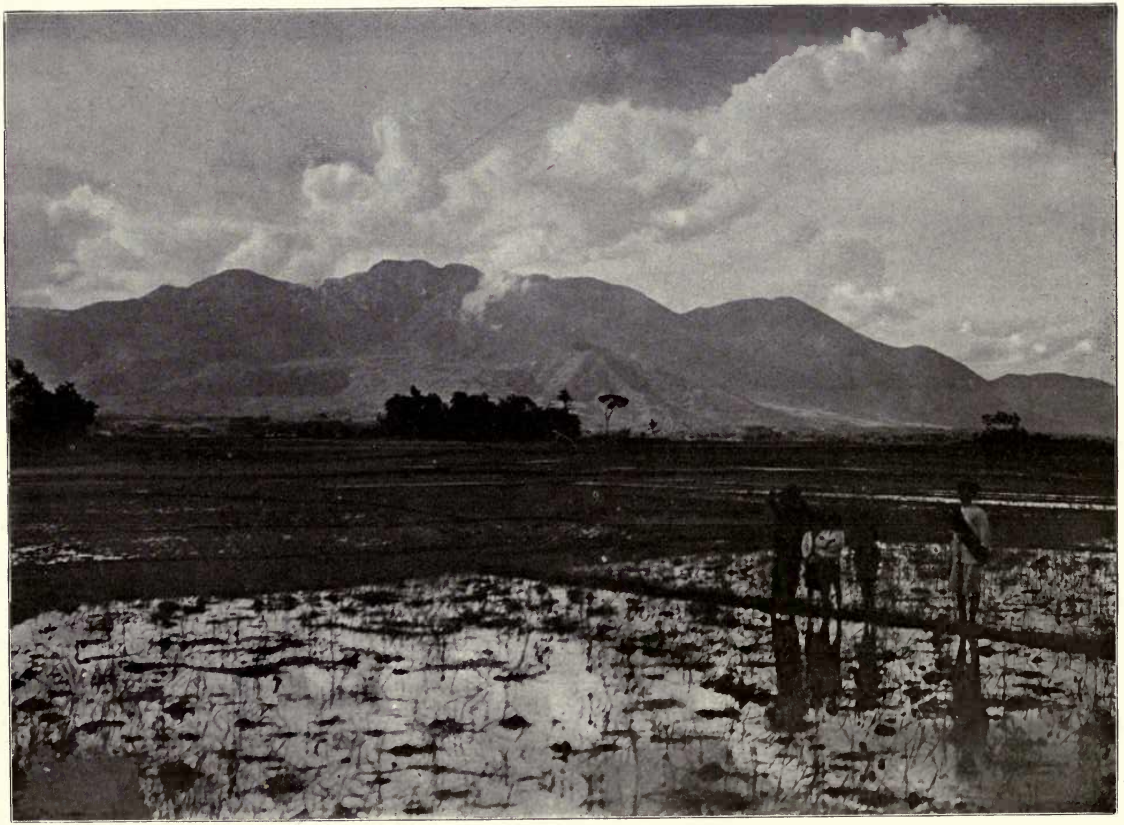

PLATE LVIII.—JAVA. GUNTUR AND PAPANDAYANG FROM PADDY-FIELDS.

XII

VOLCANOES IN JAVA

DR. ANDERSON spent about six weeks of 1913 in Java, landing there on March 25th, during which time he visited some of its volcanic districts.[1] At Buitenzorg he was much impressed by the beauty of the view from the terrace of the Bellevue Hotel, in which the Salak volcano afforded constant changes of effect, sunshine alternating with cloud and rain. From this town he went by rail to Garut, "a place surrounded by volcanoes." These, in the western part of the island, form a fine group rising from high ground, but in the eastern they are more scattered. A carriage excursion to Lake Leles afforded him attractive views of Guntur—the Black-Thunder Mountain—one of which is reproduced on Plate LVII. This rises to a height of 7,362 feet and is linked by an elevated ridge to a southern group, the Telaga Bodas Mountain, of which Galunggung and Papandayang are members (Plate LVIII).

The only active, though not the highest, crater on Guntur is

[1] He was accompanied by Mr. L. F. Taylor of Clare College, Cambridge, who has kindly identified the photographs and added some helpful notes.

Karak Kamadjan. To visit this Dr. Anderson started at dawn and drove, at first through a succession of rice-swamps and villages, steadily rising, till he left the carriage and proceeded on horseback by a well-engineered bridle-path, first through overgrown clearings and then through natural jungle, till he reached a group of old communicating craters so densely wooded as to conceal any details of their structure. In one of his letters he remarked that Guntur has "a large crater with recent craterlets in the bottom, some merely with mud puffs or hot springs, some large enough to form lakelets, but all difficult of examination or even of access, because of the overgrowth." So Plate LIX represents the best record of volcanic phenomena which he could secure on this excursion.[1] Eruptions from Guntur have been very numerous, and this fact accounts for the general barrenness of its slopes; for, though "history does not show it to have been so destructive to human life as several other volcanoes of the Island, it has nevertheless ruined the coffee plantations round it on many occasions."

The ascent of Papandayang, which rises to a height of 8,611 feet a few miles to the south-west of Galunggung, was the next excursion from Garut. It obtains its name—meaning The Forge—from the deafening noise produced by its crater. Its last eruption, according to Dr. F. H. H. Guillemard,[2] occurred in 1772 and was remarkable, not only as being one of the most destructive in the

[1] The height of the crater is about 6,500 feet above sea-level.

[2] *Australasia* (Stanford's *Compendium of Geography*, vol. ii.), p. 106. Its spelling of the names has been followed in the text.

PLATE LIX.—JAVA. POOL OF BOILING MUD ON GUNTUR.

PLATE LX.—JAVA. A VIEW OF PAPANDAYANG.

history of the island, but also for its suddenness and short duration. " A great part of the mountain is said to have been engulfed and forty villages and four thousand people were destroyed." An early drive, through rice swamps and villages, brought Dr. Anderson to the Villa Paulina, " a delightful spot " which commands fine views of the volcanic group. In the front of this is the very regular cone of Chikurai, with Guntur on the left, as well as Papandayang, which, as is shown in Plate LX, probably taken on the way up to the Villa Paulina, presents a fine pyramidal outline. At the Villa the air was " cool and refreshing, like a Yorkshire moor." From it a bridle-path ascends rapidly through old plantations, partly abandoned, partly cultivated by peasants, and after them through jungle, which is less cultivated than on Karak Kamadjan. In rather more than two hours they reached a rest-shed built on the floor of Papandayang crater. This is not only large, but also bare of vegetation, so that the structure can readily be studied. It is breached on its north-western side, below which are some pools of water and terraces with coloured algæ. East of the gap the wall consists of beds of brown stratified tuff, but west this is white, probably in consequence of solfataric fumes. In the more southern part of the crater are two or three mud-holes, but elsewhere fumaroles and blow-holes are rather common. The former deposit a considerable quantity of sulphur ; the latter, Dr. Anderson remarks, were spoiled by the guides poking them with poles in order, as they supposed, to increase their activity. The clouds, so often an enemy to the photographer in Java, kept

off only just long enough to allow him to obtain the view of the crater on Plate LXI.

Telaga Bodas—the White Lake—is a crater 5,656 feet above sea-level on the volcanic mass of Galunggung. The latter, whose summit crater reaches 7,313 feet, is now densely wooded, and could only be visited from the neighbourhood of the White Lake by cutting a path through the tropical vegetation, so that Dr. Anderson was obliged to content himself with the former. Though Galunggung has been at rest for not a few years, it bears an evil name in the history of volcanic eruptions. Its most disastrous outbreak on record occurred in 1822, and is thus described by Dr. F. H. H. Guillemard.[1]

"At noon on the 8th October, not a cloud was to be seen in the sky, and no preliminary earthquake or noises within the mountain gave warning of what was about to occur. Suddenly a frightful thundering was heard, and from the top of this apparently extinct volcano a dark dense mass was seen rising higher and higher into the air, and spreading itself out over the clear sky with such appalling rapidity that in a few moments the whole landscape was shrouded in the darkness of night. . . . Then a deluge of hot water and flowing mud shot up from the crater like a waterspout, and poured down the mountain-sides, sweeping away trees and beasts and human beings in its seething mass. At the same moment stones and ashes and sand were projected to an enormous height into the air, and as they fell, destroyed nearly everything within a radius of twenty miles, while quantities of the ejecta fell even beyond the river Tandoi, which is forty

[1] *Ut supra*, p. 107.

PLATE LXI.—JAVA. CRATER OF PAPANDAYANG.

miles off. . . . The thundering was first heard at half-past one o'clock. At four o'clock the extreme violence of the eruption was past; at five, the sky began to grow clear once more, and the same sun that at noon had shed its light over a rich and peaceful landscape, at evening was shining over the same spot, now changed into a scene of utter desolation.

"But this was not all. A second eruption followed on October 12th, even more violent than the first. Hot water and mud were again vomited forth, and great blocks of basalt were thrown to a distance of seven miles from the volcano. There was at the same time a violent earthquake: the summit of the mountain was broken down, and one side, which had been covered with forest, became an enormous semicircular gulf. The rivers bore down to the sea the dead bodies of men and the carcases of deer, rhinoceroses, tigers, and other animals. The base of the mountain could not be approached for a month, when it was found that the surrounding country had been covered with a layer of greenish-blue mud, which in places was 50 feet in depth. The official accounts state that 114 villages were destroyed and 4,000 persons killed."

Access to the crater of Telaga Bodas is not difficult, though the upper part of the path is rather steep. Dr. Anderson, with some friends, quitted the hotel at Garut at a very early hour in a carriage, and left that for horseback about three miles beyond Wanaridja. Thence he rode through coffee plantations, followed by dense jungle, to the edge of the crater, from which the margin of the White Lake can be easily reached. It is almost circular in shape, its diameter being about 700 feet, and the

inner walls of the crater—higher on the side towards Galunggung than on the other—are steep but well wooded, as the photograph shows (Plate LXII). Members of the party walked round the edge, but found the path unattractive. It was in some places rough, in others boggy. Hot, sometimes boiling, springs raise the water of the lake above the ordinary temperature, and jets of steam issue from fissures in the ground, which emit sulphurous odours. To these discharges the white colour of the water is probably due. This crater is said also to have erupted in 1822, but since then it has been at rest, like its greater neighbour.

From Garut Dr. Anderson went to Djok, a town near the south coast of Java, to visit the central and eastern volcanoes. On the journey by train he obtained some interesting views, though photography was, of course, impossible. These included the slopes of Merapi (9,404 feet) with sundry cones to the east of it, which were sometimes steeper. One of them apparently terminated in a small crater, but no steam came from its summit. Others were passed on the southern side of the railway, besides a smaller one on the northern side. "All these," he remarks, "are more or less regular cones, cultivated up to about two-thirds of their height, which, however, were not emitting any steam." A carriage took him to Pasrepan, affording him a fine view of the volcano Arjuna, with its five summits, and then brought him to Tosari.

This place, 5,830 feet above the sea, is the highest health resort

PLATE LXII.—JAVA. CRATER LAKE OF TELAGA BODAS.

PLATE LXIII.—JAVA. TENGER CRATER WITH SEMERU IN DISTANCE.

in Java, its cool dry mountain climate making its sanatorium especially suitable for the cure of malaria and nervous complaints. "It stands on a small promontory of the Tenger ridges and commands one of the most magnificent views in East Java," including the sugar-loaf shaped Penunggungan, Arjuna, and the Kawi with its three summits. The people in this district are not without interest, for they belong to a race which clung to the old half-Brahmin, half-heathen religion of the island and retreated hither on the spreading of Islam and the downfall of the realm of Madjapahit. They still retain traces of their primitive simplicity and peculiar habits.

Tosari is an excellent starting-place for the still active crater of Bromo. Dr. Anderson left the hotel about half-past three in the morning, and, after passing Old Tosari, had a long ascent by moonlight, the path winding round and across several ridges, composed, so far as he could see, of tuff and red clay, overgrown with woods, but apparently not with the original jungle. This path leads to the Mungal Pass, and affords, about half-way up to it, a fine view towards the south, of Semeru, the highest volcano (12,044 feet) in Java. Its grand cone "stands up in all its nakedness, rising from an irregularly planted girdle of olive-green woods. From time to time a white cloud of smoke ascended from the west corner" (see Plate LXIII).

The path divides at the Pass, and the left-hand branch leads, shortly but steeply, to a small platform on which a little rest-house has been built. Standing on the north-west part of the

rim, this commands a fine view of the great crater of Tenger (Plate LXIV), the longer diameter of which is about six miles and the shorter about four and a half miles. Probably this volcano once attained a greater elevation, but has been decapitated, like several others, by violent explosions during an eruption of which no record remains. Its steep walls are formed of interbedded volcanic débris, coarse or fine, and of lava, generally dark in colour, which is sometimes compact and almost vitreous, sometimes more scoriaceous; being in texture, now uniform, now speckled with small crystals of felspar. From the rest-house a track zigzags steeply down to the Zandzee, or Sea of Sand, an expanse of dark-grey volcanic sand, in which the individual grains are much the same size as those on the seashore, but instead of being formed by the wind and the waves they consist of lava, blown into dust by explosions. From the Zandzee rises a group of cones, like islands, probably thrown up after some convulsion which split Tenger to its foundations. Of these cones, Batok, the north-western, is nearest, a dome-like mass with its sides furrowed by rain and "a softly indented flat top, so regularly shaped that we might fancy we see before us a gigantic pudding-mould"[1] (see Plate LXV). Bromo, jetting out steam, rises behind Batok, and at the back of the former, indeed actually in contact with it, is the mass, now inactive, called Widodaren. This last is really composite, for it consists of a large oval crater, with its axis lying east and west,

[1] Van Bemmeleu and Hoover, *Guide to the Dutch East Indies* (1897), p. 77.

PLATE LXIV.—JAVA.—TENGER CRATER SEEN FROM ITS EDGE.

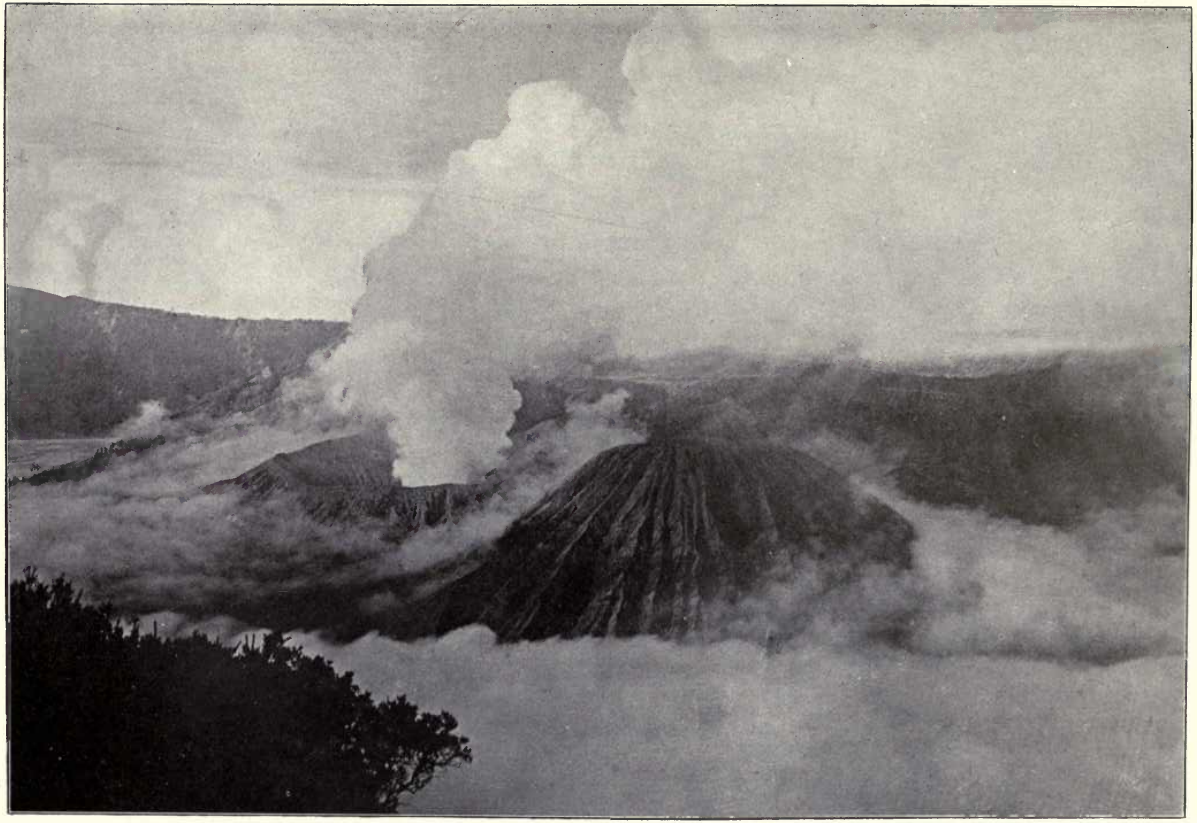

PLATE LXV.—JAVA. BROMO AND BATOK, ABOVE THE CLOUDED ZANDZEE.

PLATE LXVI.—JAVA. THE CRATER OF BROMO.

PLATE LXVII.—JAVA. BOTTOM OF THE CRATER OF BROMO.

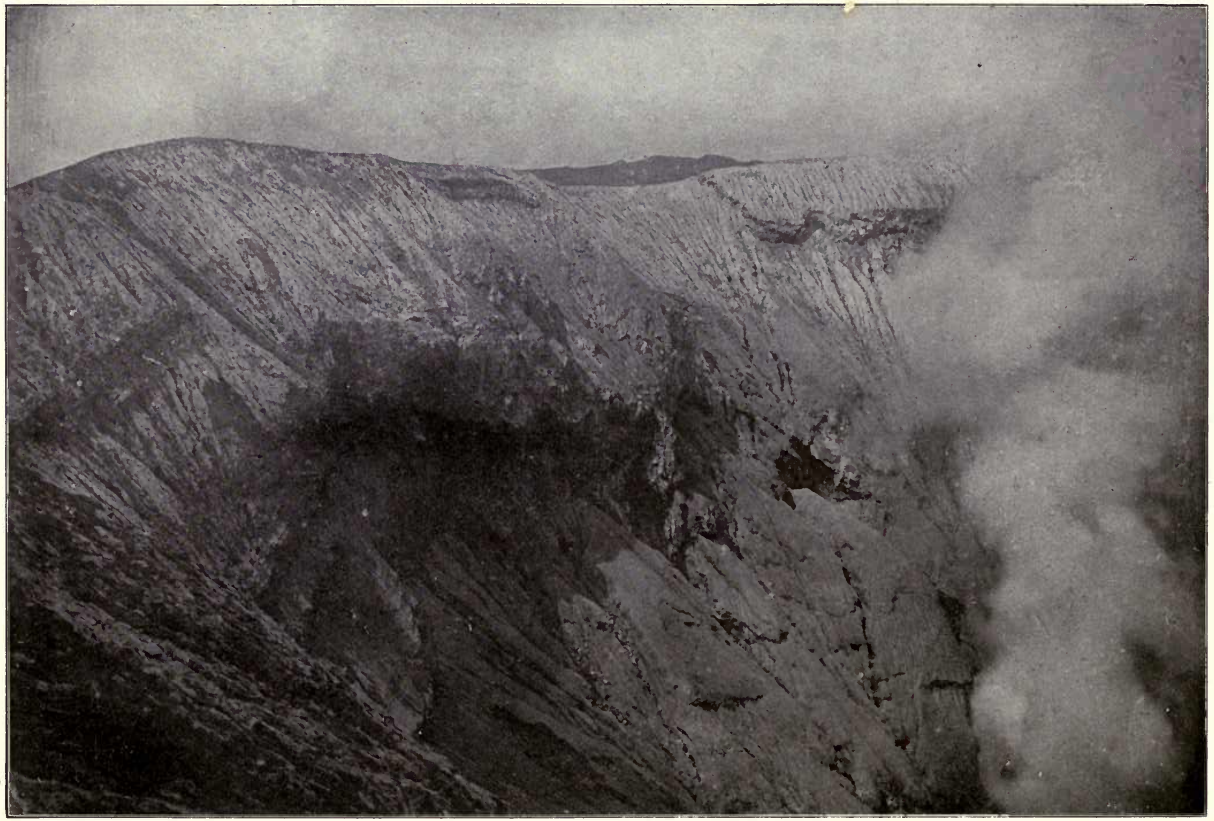

PLATE LXVIII.—JAVA. INNER WALL OF THE CRATER, BROMO.

PLATE LXIX.—JAVA. FURROWED CONE OF WIDODAREN, SEMERU IN DISTANCE.

and a smaller one, forming an irregular ring, at its north-eastern corner and in actual contact with Bromo, the crater of which is about 600 yards in diameter and as many feet in depth.

That bare black cone rising from the floor to a height of 600 feet is easily ascended under ordinary circumstances, though this would be impossible during a paroxysmal seizure, such as has ejected sundry big blocks which now lie scattered on the surface of the Zandzee, and it is not difficult to walk round the narrow edge of the crater (Plate LXVI). The volcano, as Dr. Anderson wrote in a letter[1]—

"is quite devoid of vegetation and strongly reminds one of the Soufrière, and has a crater . . . which might pass for some of the views I got in 1907, only, instead of the crater-lake, there is a very active pit in the bottom of the funnel, out of which enormous volumes of steam can escape with a continuous roar and occasional loud explosions, some of which are audible here" [at Tosari].

At the time of his visit the more violent ejections of steam occurred at intervals of about four minutes, and puffs occasionally rose some 1,100 feet above the crater. Plate LXVII shows the bottom of the crater at one of its quieter moments, and Plate LXVIII part of the inner wall mentioned in Dr. Anderson's letter; Plate LXIX, taken from the Mungal Pass, the furrowed flanks of Widodaren, rising from the level Sand Sea, while the grand cone of Semeru appears in the distance towering above

[1] Printed in the *Alpine Journal*, vol. xxviii. p. 178.

the Tenger crater-wall. Another day's excursion took Dr. Anderson to Penanjaan, the highest point on this wall, about 9,000 feet above sea-level. This he reached in two or three hours' ride from Tosari up a good path through old clearings, which have now been replanted. It commands not only a fine view of the Zandzee, but also an extensive prospect of the mountainous region of the south-eastern part of Java.

From Tosari Dr. Anderson moved to Bandong (2,300 feet), which he reached on May 1st, obtaining, as he passed along the railway, glimpses of several volcanoes, among them Merapi, from the highest part of which (9,404 feet) steam was issuing. From this town he made an excursion to Tangkuban Prahu to see the crater associated with the stories about the Upas tree. It is on a summit in a mountain range, overlooking Bandong and the lowlands on which it stands. Eruptions from it are said to have occurred in May 1846 and in the same month of 1896. A journey over this lower ground, followed by a rather steep ascent up a good road, brought him to the oval crater of Tangkuban Prahu—the upturned boat—which is about a mile in length and half that distance in breadth. This is really a double crater, the two basins, each about 600 feet deep, being separated by a ridge considerably lower than the outside wall (Plate LXIX). The eastern one, called Ratu, is the larger and a little the deeper (it begins on the right-hand side of the photograph), and on its bottom are some active fumaroles with a few pools of water, which are constantly seething and bubbling, but the bottom of the western

PLATE LXX.—JAVA. CRATER OF TANGKUBAN PRAHU (THE UPAS VALLEY).

basin is occupied by a single lakelet. Here is the Guwa Upas, or Poison Valley, the home of the fabled Upas Tree. In reality springs of carbonic acid gas issue from the ground, as at the Grotto del Cane, in the Phlegræan Fields (see *Volcanic Studies*, First Series, Plate XVI) and other like districts, which are often fatal to animals; but most of the stories, including that of the Tree and its deadly shade, are legendary. Dr. Anderson enjoyed fine retrospective views during his ascent, though the upper sky was covered with clouds; but these descended upon the summit within five minutes from the time when he reached it, so that such photographs as he obtained were only glimpses through momentary openings and are hardly worth including in this volume.

The Upas crater has a rival of even worse reputation in a valley on Galunggung not far from the Telaga Bodas Lake, which, however, Dr. Anderson did not visit. This, Pajagolan—the slaughter-place—emits from cracks in its muddy soil carbonic acid gas in sufficient quantities to be fatal not only to small animals, but even, as Junghahn asserts, to those so large as the tiger and rhinoceros. After returning to Bandong, Dr. Anderson went on to Batavia, reaching it on May 5th, from which place he made the interesting visit to Krakatau described in the next section.

XIII

KRAKATAU

KRAKATAU, the scene of the frightful eruption which culminated on August 27th, 1883, is the largest of a group of islands (all except three quite unimportant) in the Strait of Sunda, between Java and Sumatra. They are believed to be the relics of a huge cone, once about eight miles in diameter at sea-level, which was shattered in a remote past by an even greater catastrophe. The principal fragment had been enlarged by subsequent eruptions, so that it formed a hilly island, rather more than five miles in length and three miles across at its widest part, the highest cone on it, called Rakata, rising to a height of 2,623 feet above the sea.

An eruption occurred in 1680, but after that just two centuries passed without any disturbance. Earthquakes then became frequent, but the eruptive period did not begin till May 20th, 1883. On that day booming sounds, like distant artillery, were heard at Batavia and Buitenzorg, the nearer of which towns is almost a hundred miles away, and on the following morning the captain of a passing vessel saw that clouds of steam, dust, and pumice were being ejected from Krakatau, which fortu-

nately was uninhabited, to a height, as he estimated, of seven miles. The eruption continued for about fourteen weeks, sometimes slackening a little, so that parties from Batavia were able to visit the island.

Then came the great catastrophe, the account of which had to be gathered from disjointed reports, for the crews of ships which happened to be passing had enough to do in seeking an escape from the peril. Soon after midday on August 26th the island disappeared under a cloud of black vapour which rose to a height, as was estimated, of not less than seventeen miles; loud explosions were heard, and a rain of pumice began to fall. Louder and louder became the explosions, blacker and blacker the cloud, yet more widespread the darkness, the storm, and the waves, till the paroxysms culminated, on the following morning, in four great explosions, the third of them, occurring at about ten o'clock (local time), being far the most violent. By the 29th the eruption was practically at an end, but not before it had made a wreck of the island, about two-thirds of which—the northern portion—including a large part of Rakata, was blown completely away; the remainder of that cone forming a huge precipice over a thousand feet in height. Where land had been there was now sea, which in some places was more than 160 fathoms deep; but by way of compensation the island had been extended, especially towards the south, by the ejected materials. The shape of Lang Island, which formerly had been separated only by a narrow channel, was altered to some extent

by addition and subtraction ; changes also were made in Verlaten Island to the north-west, and many islets had altogether disappeared.

Enormous quantities of pumice had been hurled into the air. Much of this was so vesicular that it floated on the water, accumulating here and there in great banks, which covered the sea for miles, rising sometimes to a height of four or five feet above it.[1] Immense volumes of dust had also been discharged. At Batavia, nearly a hundred miles away, it produced an effect very similar to one of the blackest London fogs. This began about seven o'clock in the morning of the 27th, and by eleven the town was in complete darkness, while a heavy rain, mingled with dust, was falling. That lasted about two hours, and then the air gradually cleared and the light returned. Buitenzorg, which is at a still greater distance, had a similar visitation, though for a shorter time. The materials of the dust cloud had been shot up to an estimated height of about twenty-five miles above the surface of the earth, and the finer particles are believed to have floated through the air till they made more than one circuit of the globe. Their presence, it was supposed, caused the wonderful afterglows which characterised the months of November and December in England. Huge waves, started by either the earthquakes or the explosions, devastated the low-lying shores of Java, Sumatra, and other islands, and the oceanic disturbance,

[1] Mr. L. F. Taylor mentions in his notes that "the sea for a hundred yards from the island is covered with a layer of fragments of pumice."

though it soon ceased to be serious, was traced as far as Cape Horn, and possibly even to the English Channel. The report of the explosions was heard at places more than two thousand miles away and the waves of atmospheric disturbance were proved to have travelled round the earth four times out and thrice back.[1]

Dr. Anderson, with Mr. L. F. Taylor and two members of his own profession resident at Buitenzorg, left Tanjong Priok, the port of Batavia, in a small steamer about ten o'clock in the morning of May 6th, 1913. All that day they passed among beautiful islands, covered with vegetation to the water's edge, and obtained retrospective views of Salak and Gede, the latter being especially striking as they started. After a delightful voyage they reached the western end of Java, casting anchor before dusk in a safe bay. In the early dawn of the 7th they steamed for the channel between Krakatau and Lang Island (much broader now than before the great eruption), made more than a complete circuit of the former and anchored about breakfast time in front of the great cliff which now limits the cone of Rakata on its northern side. This was examined, as far as was possible, from a launch and from the shore, especially in its more central part where the dykes are more numerous. Photographs were taken to illustrate the marvellous sections made by the explosions, with one or two to give an idea of the vegetation which, in the course of thirty years, had sprung up wherever it could obtain a footing.

[1] Stanford, *ut supra*, p. 169.

PLATE LXXI.—KRAKATAU. NORTHERN SIDE OF RAKATA.

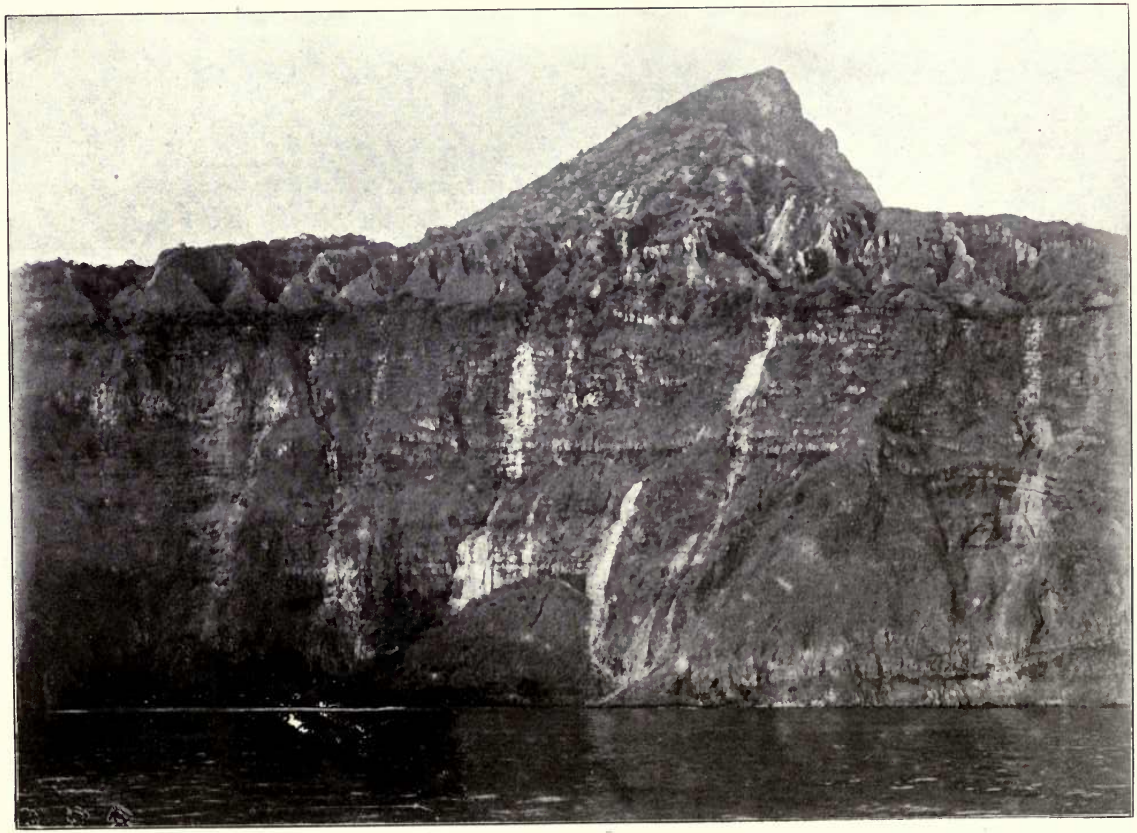

PLATE LXXII.—KRAKATAU. LAVA BEDS AND DYKES OF RAKATA.

PLATE LXXIII.—KRAKATAU. THE BROKEN FACE OF RAKATA.

PLATE LXXIV.—KRAKATAU. DYKE AND CLIFF ON RAKATA.

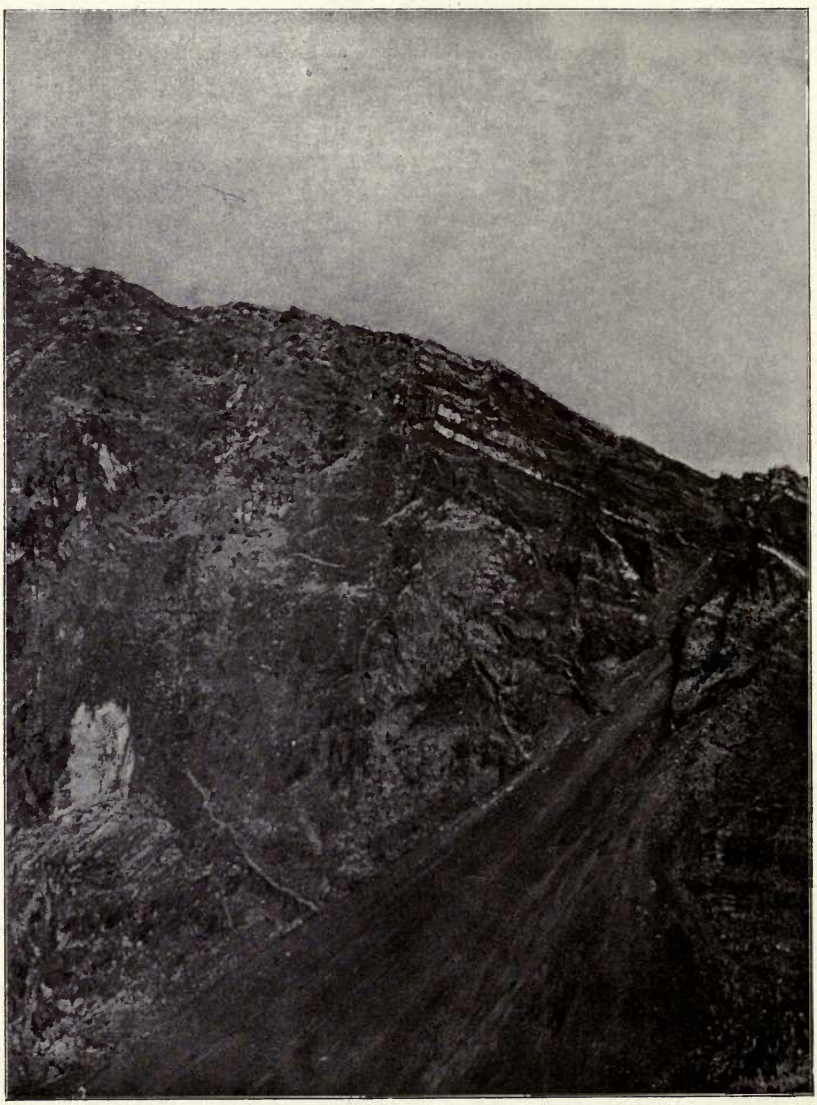

PLATE LXXV.—KRAKATAU. CRAGS AND SCREE ON RAKATA.

PLATE LXXVI.—KRAKATAU. THE RETURN OF VEGETATION.

A view of the northern side of Krakatau is given in Plate LXXI. This shows the remnant of Rakata rising as a peak above crags and the slopes of débris ejected in the eruption of 1883, which are now carved into gullies by the tropical rains. On Plate LXXII, taken from the launch, we see Rakata rising behind the great cliff which, as described above, now forms the northern face of Krakatau. This, with Plate LXXIII, exhibits the broken edges of the lava beds which helped in building up the great central cone of the original volcano (destroyed, as has been stated, in a remote past), the dykes by which they have been riven, and the tracks of temporary cascades. Plate LXXIV represents one of these dykes, running up the face of the crags where they are becoming lower towards the eastern end, with a distant view of land, probably part of the island of Java, to the west of the landing-place. Dr. Anderson photographed a fine scree (Plate LXXV) which, as he records, reminded him of the sciarra on Stromboli (*Volcanic Studies*, First Series, Plate XXI), though of course there is no crater here, and it must be due, not to ejection, but to ordinary downfall of rock. From Plate LXXVI we can obtain some idea of the rich vegetation which has sprung up wherever the crags were not too steep or the pumiceous scoria too arid.

Lang Island, Dr. Anderson mentions, is deeply covered with ash which shows the characteristic erosion forms, but his party did not touch at either it or Verlaten Island, nor did they leave

their anchorage beneath the cliff till night was falling.[1] Then they steamed back to Java, and by eight o'clock in the morning were landed at Tanjong Priok. Two days afterwards Dr. Anderson quitted Java for Singapore, going thence to Hongkong, which he reached on May 21st on his way to the Philippine Islands.

The history of the great eruption is told in a separate volume of the *Philosophical Transactions*, "Eruption of Krakatoa[2] and Subsequent Phenomena: A Report of the Krakatoa Committee of the Royal Society," published as a companion volume to the *Philosophical Transactions* by the Society in 1888, which has been used in drawing up the earlier paragraphs; or to speak more correctly, they are a rather shortened version of the abstracts made when writing my book on volcanoes published in the Progressive Science Series. The later part is founded on Dr. Anderson's too brief notes of a day which must have been of the highest interest, with some by Mr. L. F. Taylor. As usual, he remembered my wants, for after his death I received from his representatives a collection of volcanic rocks from Java, among which were half a dozen excellent specimens from Krakatau. These are now preserved in the Sedgwick Museum at Cambridge.

[1] They were to some extent hindered by the heat, which, as Mr. Taylor records, "was absolutely stifling, worse than anything we have had yet. The rocks are so hot that we cannot touch them with our hands."

[2] My friend Dr. F. H. H. Guillemard informs me that the correct spelling of the name is Krakatau and not as in this Report. He passed the island after eruption had begun, as described above, but before the great catastrophe.

PLATE LXXVII.—LUZON. CAMIGUAN FROM THE SEA.

XIV

VOLCANOES IN LUZON

FROM Java Dr. Anderson went to Luzon, the most northern and important island in the Philippines, landing at Manila on May 23rd, 1913.[1] From this city, after visiting the noted Taal volcano, as will presently be described, he travelled in a coasting steamer round Luzon, which gave him some opportunities of obtaining photographs of the scenery and other matters of interest, as it went by way of the western coast and returned by the eastern. From the northern end of Luzon scattered islands extend in that direction, the most important being the volcanic masses of Camiguan and Babuyan Claro, both of which are occasionally active. Of these the former, according to Dr. Anderson's notebook, has three cones, the highest being 2,747 feet above sea-level; the latter has two cones, one of them reaching 3,800 feet. It is not quite clear from his memoranda which of the two is that prominent on Plate LXXVII, but as it has three summits it is probably Camiguan, and the distant one Babuyan Claro. The island of Dedica, to the east of these, marks the

[1] He finally left Manila at the end of July, having obtained, as in Java, many photographs of ethnological interest.

spot where a volcano rose from the sea about sixty years ago and was afterwards, like Graham's Island in the Mediterranean, almost destroyed by the waves.

Near the extreme south-eastern corner of Luzon the grand isolated volcano of Mayon (Plate LXXVIII) rises above the little town of Albay to a height of about 8,970 feet, one of the most perfect cones of that elevation in the world. The first eruption known to the Spaniards was in 1616; another, which did much damage, occurred in 1766, but that of February 1st, 1814, was—

"one of the most appalling of the many volcanic catastrophes which have visited the islands of Australasia. The rain of ashes was such as to bury whole villages and their coco-nut groves to a depth of 120 feet or more, and more than 12,000 people lost their lives. In Manila, 208 miles distant, the ashes lay nearly two feet deep in the streets. Since then eruptions have been very frequent, but not so violent." [1]

In south-western Luzon the noted Taal volcano forms an island in the Taal or Bombon Lake, which is so surrounded by steep hills as to resemble a huge cauldron of water. But it is a gigantic one, for it measures about seventeen miles in length and eleven in width.[2] The surrounding district consists of volcanic tuffs, and some authorities think that the lake marks the site

[1] Dr. Guillemard, *ut supra*, p. 73.

[2] It is described with illustrations from photographs in a memoir by Mr. George I. Adams in the *Philosophical Journal of Science*, vol. v. p. 57, and more briefly by Dr. Guillemard, *loc. cit.* p. 74.

PLATE LXXVIII.—LUZON. THE CONE OF MAYON.

of a large and lofty cone which has been destroyed, partly by explosions, partly by the engulfment of great masses of the mountain. The island, commonly called the Taal volcano, is wholly volcanic and has probably been built up by eruptions of still later date than the catastrophe by which the lake was formed. It is spotted with numerous small subsidiary cones, and is only 767 feet at the highest point of its rim, being generally much lower than this. In outline its crater is an irregular oval and in its widest part is about three-quarters of a mile across. From the lowest part of the rim, that nearest the shore, the bottom of the crater, which is about on a level with the lake outside, can be easily reached. On it are two lakes, containing, one yellow water, another green water. The former is shallow and hot, but not boiling, the latter gives off steam from its surface and boils violently near its southern border. To the south of this is a circular crater on the floor of which are spots with boiling mud, which, however, give off but little vapour, and at the base of the outer slope is a vent from which steam is discharged with great force. Some blocks of lava are scattered about on the surface of the ground, but neither flows nor dykes are visible, and the crater is apparently built up by successive beds of volcanic débris, which dip outward from its centre and are made more conspicuous by their differences in colour. In fact it is a huge cinder-cone. Several eruptions are on record during the last two centuries, the most severe being—

" that of 1754, when for eight days the crater threw out ashes and lava, darkening the sky to such an extent that artificial light had to be used at midday in Manila, while the shocks of the explosions were sensible at a distance of 300 leagues. The red-hot lava falling into the lake raised the temperature of the neighbouring water to boiling point, and the fish, perishing in countless thousands, gave rise to an epidemic which is said to have cost the lives of 40,000 of the natives." [1]

An eruption, but not a severe one, occurred in 1904, which, according to Mr. Adams, is the first one of which photographs have been published. Those taken by Dr. Anderson represent (Plate LXXIX) the Taal Lake with the enclosing cliffs of stratified tuff, another view of the same (Plate LXXX) showing also a marginal terrace indicative of a fall in the lake-level; and the outer slope of that volcano (Plate LXXXI), probably taken not far from the usual landing-place.

[1] Dr. Guillemard, *ut supra*, p. 75.

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PLATE LXXIX.—LUZON. THE TAAL CRATER.

PLATE LXXX.—LUZON. INSIDE THE TAAL CRATER.

PLATE LXXXI.—LUZON. THE TAAL CRATER, OUTER SLOPE.

Storage